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Monterey, California

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UNMANNED AERIAL VEHICLE/REMOTELY PILOTED AIRCRAFT DESIGN SELECTION BASED ON SERVICE-STATED METEOROLOGICAL/OCEANOGRAPHIC REQUIREMENTS

by

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March 1999

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A decision tool for choosing most efficient unmanned aerial vehicles (UAV's)/remotely piloted aircraft (RPA) for Meteorological/Oceanographic (METOC) data collection is presented. A Microsoft Access database query (written in Structured Query Language) links RPA flight performance parameters to individualized METOC Elements of Measurement, a subset of a larger Joint Service METOC Requirements database table, presented elsewhere in the thesis in full. Successful aircraft performance parameters include vast controllability/programmability ranges, flexible (including shipboard) launches and recoveries, atmospheric profiling capabilities, hover ability, long endurance and airframes free of propeller or rotor wash. A sampling of existing (or planned) airborne METOC instrumentation, their ranges and accuracies are included, in database form, for further reference.

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UNMANNED AERIAL VEHICLE/REMOTELY PILOTED AIRCRAFT DESIGN SELECTION BASED ON SERVICE-STATED METEOROLOGICAL/OCEANOGRAPHIC REQUIREMENTS

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ABSTRACT

A decision tool for choosing most efficient unmanned aerial vehicles (UAV's)/remotely piloted aircraft (RPA) for Meteorological/Oceanographic (METOC) data collection is presented. A Microsoft Access database query (written in Structured Query Language) links RPA flight performance parameters to individualized METOC Elements of Measurement, a subset of a larger Joint Service METOC Requirements database table, presented elsewhere in the thesis in full. Successful aircraft performance parameters include vast controllability/programmability ranges, flexible (including shipboard) launches and recoveries, atmospheric profiling capabilities, hover ability, long endurance and airframes free of propeller or rotor wash. A sampling of existing (or planned) airborne METOC instrumentation, their ranges and accuracies are included, in database form, for further reference.

DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at risk of the user.

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ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Philip A. Durkee, Department of Meteorology, second reader Dr. Carlyle H. Wash, Chairman of the Department of Meteorology and SQL guru Dr. Daniel R. Dolk, Department of Information Technology Management, Naval Postgraduate School, for their guidance and support during the development of this perhaps somewhat unusual thesis. Additionally, I owe Mr. Tom Knopp of the Fleet Numerical Meteorology/Oceanography Center a debt of gratitude for his support and patience in getting me started with Microsoft Access as well as for the kernel of the column assignment idea.

My most sincere thank you, however, is to my wife Barb and children Mitchell, Elizabeth and Summer. Without their understanding and patience over the years (toward a husband and father forever buried in homework) this project could have never been contemplated. Hang on guys, Daddy's almost got his evenings and weekends back.

I. INTRODUCTION

The initial and perhaps most profound assumption motivating this thesis is that the collection of Joint Service (Air Force, Army, Marines, Navy) Meteorological and Oceanographic (METOC) operational measurement deficiencies could and will warrant dedicated Unmanned Aerial Vehicle (UAV)/Remotely Piloted Aircraft (RPA) missions in the near future. We believe this assumption is inevitable due to the process of education by example, aided by scientific and technological advances.

The following anecdotal description of the events surrounding Operation Eagle Claw amply illustrates a case where UAV/RPA's could have been employed to great advantage (Bates and Fuller, 1986). On April 24, 1979 (dusk), eight U.S. Navy RH-53D Sea Stallion helicopters disembarked from the USS *Nimitz* (in the Gulf of Oman) en route Desert One (in Iran). Six helicopters were essential for the hostage rescue attempt. Shortly after landfall one helicopter aborted due to mechanical difficulties. The remaining seven ran into several walls of suspended (unforecast) dust outside Bam, Iran. Eventually, while still flying through dust clouds, a second helicopter aborted due to multiple navigational and flight instrument failures and followed the first back to the *Nimitz*. The remaining (minimum set) six helicopters touched down safely at Desert One where yet a third helicopter experienced a mission-ending hydraulic problem. Operation Eagle Claw was aborted.

While aborting, thirty-six engines of (already present) C-130s and the RH-53Ds caused further visibility problems. Attempting to refuel, a helicopter crashed into the nose of a C-130 refueler when the helicopter pilot lost vision in his own rotor blade-generated dust clouds. Both aircraft burned and eight crewmembers died.

Upon examining the Air Weather Service (AWS) operational support, an initial white paper concluded that the forecasts (for the entire operational area) had been accurate except for predicting the dust. An independent study group (of distinguished

AWS alumni) concluded that its forecasts had been as accurate as data and technology would permit. C-130 weather reconnaissance aircraft had been used neither in their reconnaissance nor pathfinder roles due to tight security surrounding the mission. Furthermore, the Defense Meteorological Satellite Program (DMSP) orbiting satellite could not spot low dust clouds at night. Ultimately, the RH-53D pilots never suspected suspended dust as a flight hazard and therefore never prepared for it (Bates and Fuller, 1986). A third inquiry (of senior-ranking officers) concluded that a high helicopter failure rate and (unforecast) en route low visibility flight conditions led to mission failure for Operation Eagle Claw.

Properly designed, outfitted and programmed, a squadron of remotely piloted aircraft (with today's technology) could have selectively meteorologically sampled the entire theater of military operations. They could have collected measurements such as temperature and relative humidity (fog avoidance), flight-level winds and atmospheric contaminants (inflight hazard avoidance and fuel planning) or the progression of solar shadow zones behind high-relief topography (stealthy approach of low flying aircraft). The extremely short counter detection ranges of these impressively capable air vehicles would have made them an excellent choice for the reconnaissance and planning of Operation Eagle Claw.

The world has since experienced an explosion of UAV/RPV-friendly METOC airframes and sensors. One example is the 21 August 1998 successful trans-Atlantic flight of Environmental Systems and Services' autonomous aerosonde "Laima." The 13 kg unmanned aircraft flew from Bell Island Airport, Newfoundland to DERA Benbecula Range, Outer Hebrides maintaining an average fuel economy of 1380 mile/US gallon. Laima flew completely autonomously (i.e. no radio communications) for 25 h 38 min of its mission. (Aerosonde Project, 1998) See Figure 1.1

Laima logged Global Positioning System (GPS) locations and altitudes and wind directions and speeds along its entire track. Although the Operational Phase I Aerosonde

has the capacity to carry three Vaisala RSSS901 dropwindsondes to measure temperature, pressure and humidity, none were deployed on this flight. Figure 1.2 shows the wind direction (blue) and speed (red) the Aerosonde measured. The heavy lines are en route winds predicted by the National Center for Environmental Prediction (NCEP) Aviation Model.

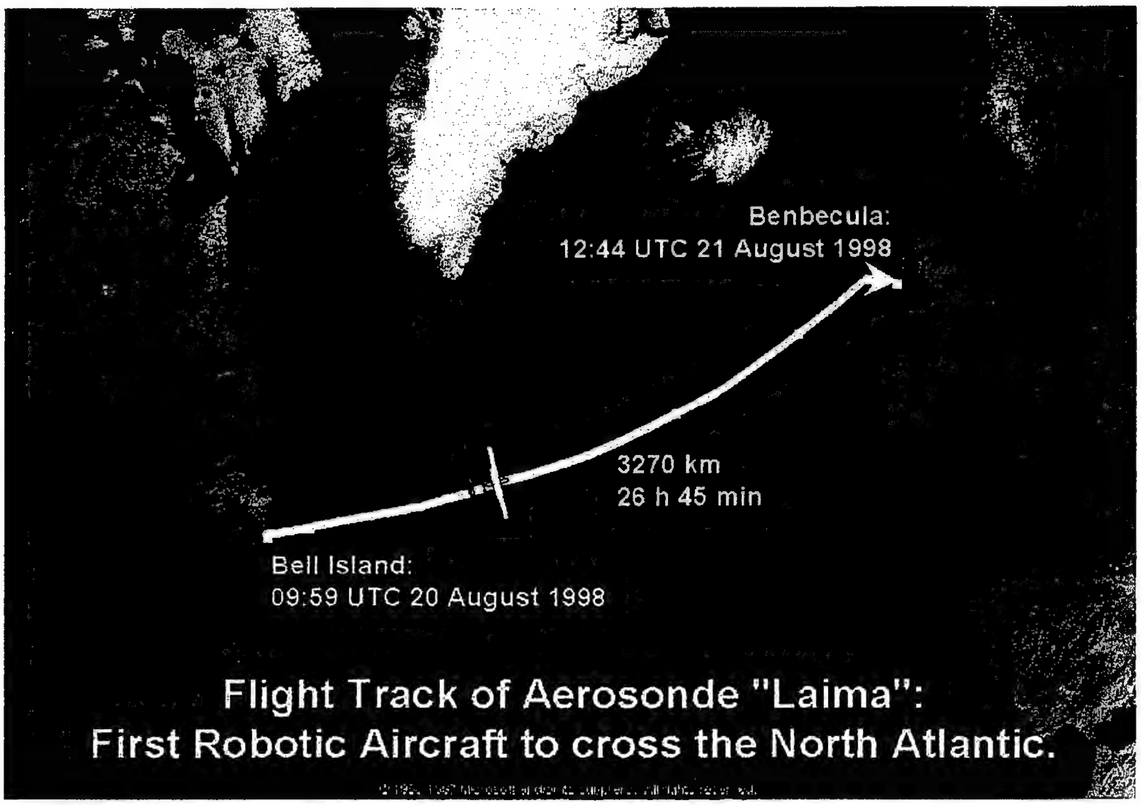

Figure 1.1. Flight track of Aerosonde "Laima."
(http://www.bom.gov.au/bmrc/meso/New/Aerosonde/laima.htm Aerosonde Project, 1998)

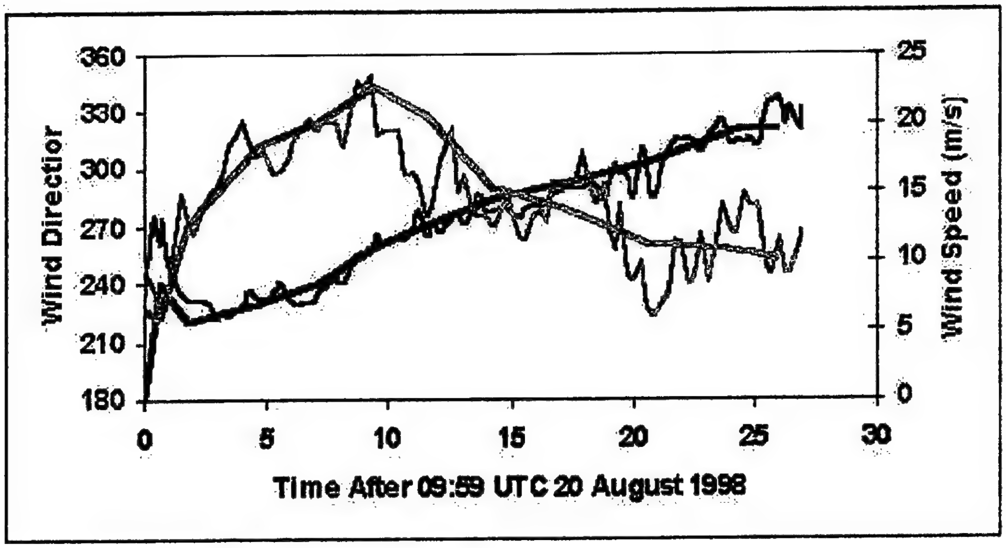

Figure 1.2. Aerosonde measured winds (light lines) vs. NCEP Aviation Model forecast winds (heavy lines). (http://www.bom.gov.au/bmrc/meso/New/Aerosonde/laima.htm Aerosonde Project, 1998)

Development efforts for the microminiaturization of multiply capable weather stations have been no less impressive. Space Computer Corporation's Micro Weather Station (MWS) is shown in Figures 1.3 and 1.4.

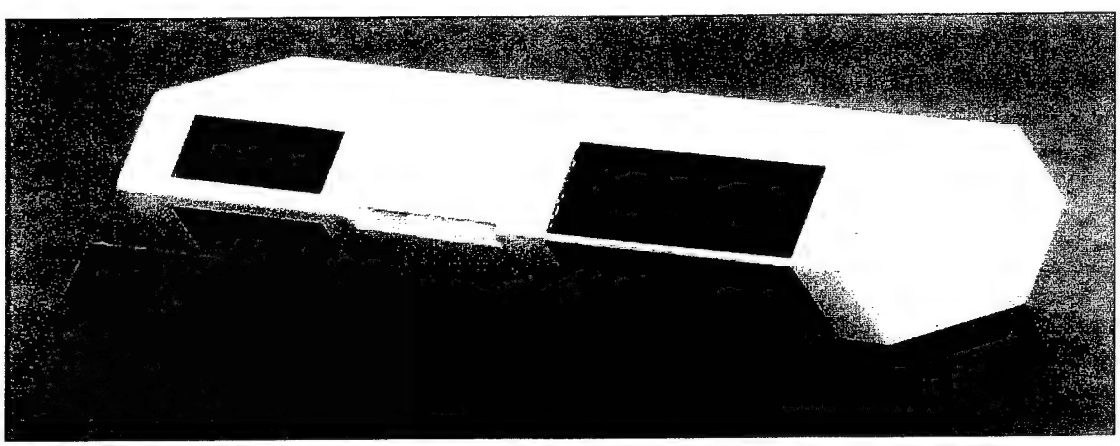

Figure 1.3. Space Computer Corporation's Micro Weather Station (MWS). (http://www.spacecomputer.com/mmw.html Space Computer Corporation, 1998)

Measuring approximately 1.5" x 2.5" x 6.5", the MWS is designed to collect meteorological and other environmental data in littoral areas. The MWS fits within the

(Air Force and Navy) military standard ALE-47 chaff/flare dispenser. When ruggedized the MWS will withstand the high g-forces associated with aircraft ejection and parachute landing. It will also be outfitted with a miniaturized microwave transmitter to allow the utilization of commercial satellites to provide near-real-time data transmission.

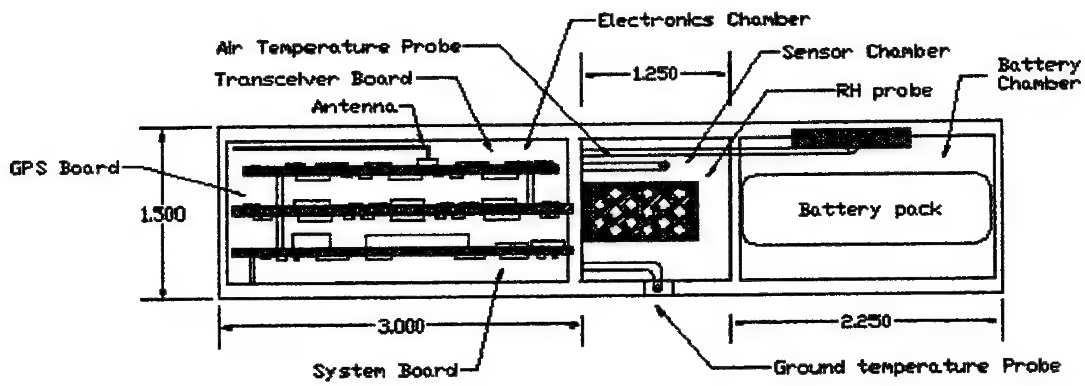

Figure 1.4. Space Computer Corporation's Micro Weather Station (MWS), wiring diagram. (http://www.spacecomputer.com/mmw.html Space Computer Corporation, 1998)

As with RPA airframes and sensors, operating radii, communicability and interoperability of these air vehicles have greatly improved. Spotlighting seamless interoperability was the June 1996 flight of a Predator RPA when it was handed-off to pilots and payload operators embarked in the torpedo control room of the USS *Chicago* (SSN 721) in support of a Special Operations Forces exercise. Multiple, in-flight hand-offs of the Predator were accomplished between the afloat (littoral water) fast-attack submarine and a shore-based Ground Control Station with and without coordinating voice communication (the remote Ground Control Station conducted the launches and recoveries). This event realized the achievable goal of a submarine, on-scene tactical commander having direct, real-time control of a remotely-piloted aircraft, greatly extending his "eyes" and "ears" beyond that of a traditional periscope. The Naval Research Laboratory has addressed potential mission-threatening RPA enroute weather avoidance (Naval Research Laboratory, 1993).

Research Laboratory has addressed potential mission-threatening RPA enroute weather avoidance (Naval Research Laboratory, 1993).

Implied in the initial assumption of METOC missions warranting their own dedicated RPA flights is the expectation RPA operators would be as opportunistic as possible in the collection of diverse METOC parameters (maybe not affecting their present mission). Of course they would have to possess knowledge of those more diverse requirements

The objectives of this thesis are twofold:

- Present three separate and distinct (upgradeable, updateable) database tables;

  (1) remotely piloted aircraft performance parameters, (*tblUAV (flat file)* table)

  (2) airborne meteorological instrument measurement capabilities, (*tblAirInstrCaps* table)

  (3) Joint Service METOC requirements (*tbl1Joint (flat file)* table).

- Determine optimal RPA performance parameters to most efficiently capture Service-stated METOC requirements by linking the *tblUAV (flat file)* to a subset of the *tbl1Joint (flat file)* table.

Chapter II describes construction of the database tables. Chapter III outlines procedures and data, Chapter IV the results obtained therefrom. Chapter V discusses final conclusions and recommendations.

II. DATABASE TABLE CONSTRUCTION

Following the initial assumption of METOC missions warranting their own dedicated RPA flights, more practical assumptions lead to designing optimal operational RPA prototypes for the capture of Joint METOC requirements. Following is a list of additional assumptions and philosophies used in the study:

- Payload capacity of an RPA was not considered in the consideration of meteorological equipment. Embedded in this assumption is the belief that microminiaturization technology will ultimately enable extremely wide ranges of METOC sensors to be carried on any one RPA,

- RPA's were considered merely as flying chassis, with no predetermined meteorological measuring abilities. Spatial, temporal and unperturbed air stream classifications were assigned from an overall view of each RPA,

- Service METOC Requirement Elements of measurement, e.g. absolute humidity, barometric pressure (surface, profile, upper air), dew point, relative humidity (surface, profile, upper air), temperature (surface, profile, upper air), wind (surface, profile, upper air), etc., were all ranked equal.. The purpose was to find the broadest range of METOC Elements measurable by a particular (or group of) remotely piloted aircraft,

- No database interrelationships were established to indicate the existence of an instrument to measure a specific METOC Element or to monitor whether a particular instrument would satisfy METOC Element accuracy requirements.

A. JOINT METOC REQUIREMENT TABLE

The Joint METOC Requirement Table fields were constructed as a merger of Navy/Marine and Air Force/Army stated requirements. The Chief of Naval Operations' Oceanographer of the Navy (CNO N096) provided databases of ten separate Navy/Marine Corps Warfare Area Requirements, very recently collected (circa 1998) directly from those Warfare Areas: Anti-air Warfare (AAW), Amphibious Warfare (AMW), Anti-Surface Warfare/Over the Horizon Targeting (ASUWOTHT), Logistics and Sealift, including Joint Logistics Over the Shore - JLOTS (LOGSEA), Mine Countermeasures/Mine Warfare (MCMMIW), Operations Other than War (OOTW), Special Operations (SPECWAR), Strike Warfare (STW), Space, Information Warfare, Communications, Command and Control Warfare (SIWCC), and Undersea Warfare (USW) (Chief of Naval Operations Oceanographer of the Navy, 1998). An analogous Air Force/Army construction, the Theater Battle Management (TBM) Gridded Data Matrix of 21 February 1997, was converted to database form and merged with the aforementioned Navy/Marine Corps databases.

The Navy/Marine Corps-merged Warfare METOC requirements were compared against the CNO N096 prioritized list of METOC Oceanography Requirements Status Reports (ORSR's) Priorities I and II to ensure general conformity. The Air Force/Army Gridded Data Matrix was compared against the Air Force Weather Mission Support Plan-97, Air Force Weather Development Plan, and the Air Force Weather Strategic Plan (1 August 1997). Some elements had to be added to round out the field (e.g. Barometric Pressure was an element. Added fields were Barometric Pressure (surface), Barometric Pressure (profile) and Barometric Pressure (UA)).

The "Element" column of the table was then extracted and configured to consist of unique METOC Elements. Each Element was further assigned spatial, temporal and air stream attributes (by a panel of experts) to facilitate relationships with the RPA Table. This table was seen as the "driver" to generate a "top-down" design philosophy, i.e. the desired RPA performance parameters generated would be exclusively defined by Joint Service

METOC Requirements. The Joint METOC Requirement Table is included, in its entirety (before Element column extraction and modification), in script form in Chapter III.

B. RPA DETAIL TABLE

The RPA detail table fields were primarily filled with information obtained from Jane's Unmanned Aerial Vehicles and Targets 09, 1997 (Jane's Information Group, 1997) and other open source material (e.g. Aviation Week and Space Report, etc.). All airframe types that had some payload capacity were considered, including, for example; remotely controlled balloons, helicopters, aerial targets, artillery targets, monoplanes, etc. For relational concerns each RPA was considered as a flying chassis, imbued with no particular METOC requirement-gathering advantage except its general proximity to potentially gather requirements (e.g. surface, surface and upper atmosphere or upper atmosphere). As with the Joint METOC Elements, spatial (horizontal and vertical), temporal and air stream attributes were assigned based on the individual character of each RPA.

C. AIRBORNE INSTRUMENTATION TABLE

The Airborne Instrumentation table field framework (and some airborne equipment entries) was taken from the December 1995 Federal Directory of Mobile Meteorological Equipment and Capabilities (FCM-I5-1995).(U.S. Department of Commerce, 1995) The directory (no longer maintained) "...objectively catalogs mobile meteorological equipment, software, and capabilities possessed by Federal departments and agencies for the express purpose of facilitating interagency cooperation in the use and acquisition of these capabilities." Using the directory format as a shell, airborne meteorological equipment from selected research agencies such as the Naval Postgraduate School's Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS), Atmospheric Radiation Measurement Unmanned Aerospace Vehicle (ARM-UAV) and the National Center for Atmospheric Research (NCAR) were included. This

table is not linked to the RPA Table or the Joint METOC Element Table. It is presented solely as an aid to the airborne instrument designer/planner who has selected an optimal RPA frame for the METOC Elements he/she wants measured and wants to research existing instrumentation.

The present database table design encourages new entries, i.e. any updated, modified or new fields will easily be accommodated and available for immediate query. Users are encouraged to "pull" the database from the World Wide Web site at www.met.nps.navy.mil/thesis/rstanton and experiment with their own assignment entries.

III. PROCEDURES AND DATA

The Joint METOC Requirements Table, as mentioned and described in Chapter II, is presented in it's entirety (422 rows, Table 3.1). If an entry in the Joint METOC Requirements Table's Element column is listed more than once, the entries came from multiple Service sources or different warfare areas within Services. Every duplicate entry in this column will be different somewhere among the remaining columns (e.g. an Army Infantry vs. Navy SEAL entry for Moisture Profile; critical values, update requirements, spatial coverages differ). The Joint METOC Requirements Table's Element column is then categorized, modified and presented in Table 3.8 (185 rows) as the Joint METOC Element Table. Each entry in Table 3.8 is further assigned spatial, temporal and air stream scales (Tables 3.2 & 3.3, 3.4, 3.5 & 3.6, 3.7) according to the following protocol.

Table 3.2 (**H1**) reflects the magnitude or scale of horizontal space coverage necessary to adequately measure a METOC Element and Table 3.3 (**H2**) refines where the measurement is required including land, coastal, water or combination thereof. Table 3.4 (**V**) accounts for the vertical character of METOC Elements, ranging from ocean bottom to upper atmosphere. Table 3.5 (**T1**) reflects how long it would take to adequately measure a METOC Element and Table 3.6 (**T2**) further determines maximum elapsed time between measurements. Table 3.7 (**UAS**) reflects whether a stated METOC Element requires an unperturbed air stream to conduct its measurement.

Subsections of the RPA Table (Table 3.9) illustrate existing or planned remotely piloted aircraft throughout the world today; remotely-piloted helicopters, dirigibles, artillery and towed targets, monoplanes, etc. Assigned to each type of RPA airframe are the same spatial, temporal and undisturbed air stream scales, (Tables 3.2 & 3.3, 3.4, 3.5 & 3.6, 3.7) as were assigned to the Joint METOC Elements, with the following additions: In Table 3.3, a land-based RPA was considered a 1, or COMBINE, if it possessed greater than eight hours endurance and was not limited to a 150 kilometer or less mission radius

(datalink range, fuel consumption, etc.). A land-based RPA was assigned a 2, or LAND, if it possessed a mission radius less than or equal to 30 kilometers. A land-based RPA was assigned a 3, or LAND/LITTORAL if it's mission radius extended anywhere from 30 km to 150 km.

In Table 3.5, an RPA could only achieve a 1, HIGH AMOUNT OF TIME (>1min.) if it could hover. An assignment of 3, MEDIUM AMOUNT OF TIME (1sec. - 1 min.) was assigned to the Insitu Aerosonde, which due its size and maneuverability can perform tight, spiraling profiles. Therefore the minimum volume of air an Aerosonde occupies during one spiraling profile defines the MEDIUM assignment. The assignment of 2, LOW AMOUNT OF TIME (<1 sec.) was made to all other (non-hovering, non-tightly spiraling) airframes.

Additionally, in Table 3.6, an RPA was assigned a 1, or HIGH REFRESH RATE (<1 hr.) if it possessed endurance of greater than or equal to 6 hours (non-hovering airframe) or greater than or equal to 8 hours (hovering airframe). This is admittedly the most arbitrary assignment throughout the thesis. A researcher would have to further consider a cost/benefit analysis of operating a squadron of candidate UAV's, etc., before determining the airframe's capability to meet desired areal or volumetric coverage. An RPA was assigned a 3, or MED REFRESH RATE (1hr. - diurnal) if it possessed endurance of 3 to 6 hours (non-hovering airframe) or 3 to 8 hours (hovering airframe).

Table 3.7 indicates a Joint METOC Element/RPA's requirement for/provision of unperturbed air stream measurements.

Table 3.9 is the Structured Query Language (SQL) query written in Microsoft Access linking the RPA Table to the Joint METOC Element Table in terms of spatial, temporal and air stream attributes. Its coding is the decisive element in interrelating the static, otherwise individual database Tables into dynamic subsets of useable data to multiple audiences. It is the fulcrum of the thesis.

Next, portions of the Airborne Instrumentation Table are displayed (Tables 3.10 through 3.30), indicating operational, research and development or transitional air vehicle

compatible METOC measuring instruments and/or equipment, their ranges and accuracies.

Table 3.1. Joint Requirements Table. (Chief of Naval Operations Oceanographer of the Navy (CNO N096) and Air Force Theater Battle Management (TBM) Gridded Data Matrix, 21 February 1997).

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Absolute Humidity	5 %					
Aerosols	concen. of particles >2.0 microns	.5 micron particles	near real time			daily
Aerosols	concen. of particles >2.0 microns	.5 micron particles		12 hr	50 km²	
Air Turbulence	55 kt or 10 diff. across front	±1 wind shear category	near real time			daily
Air Turbulence	55 kt or 10 diff. across front	±1 category		2 hr	100 km²	
Ambient Noise	TBD					
Anchorages	in OPAREA	±10 m	2 yr			annually
Anchorages	within 5 km of IUSS sensor	±10 m	2 yr			annually
Aquaculture Areas	occurrence in OPAREA	no	yearly			no
Archeological Sites/Wrecks	occurrence in OPAREA	±10 m	2 yr			yes
Atmospheric Contaminants	TBD					
Atmospheric Transmissivity	TBD					
Atmospheric Visual Range	TBD					
B-Field	high mag. field at DC-100 Hz in OPAREA	±0.1 nT	72 hr	72 hr	100 km²	none
Barometric Pressure	<1000 mb	yes	3 hr			continuous
Barometric Pressure	<960 mb	yes	15 min			continuous
Barometric Pressure	<960 mb	yes	3 hr			continuous

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Barometric Pressure (profile)	TBD					
Barometric Pressure (UA)	TBD					
Beach Characteristics	composition; features	±1/8 mm type, size; >1 m vert.	seasonal			remote sensing
Beach Characteristics	composition; features	±1/8 mm type, size; >1 m vert.		annual	50 km²	
Beach Slope	>5	±.25 angle	annual	annual	10 km²	remote sensing
Biological Noise	high AN within 50 km of OPAREA	±10 dB	12 hr			limited
Biological Noise	occurrence in OPAREA	±10 dB	12 hr			limited
Bioluminescence	condition that allows visible detection at <10 ft depth	±1 m	monthly			on demand
Bioluminescence	condition that allows visible detection at <10 ft depth	±1 m, Near-Real Time for Requested Areas	24 hr	24 hr	50 km²	on demand
Bottom Composition	75% burial in mud; or rocky	±1/8 mm	seasonally			annual
Bottom Composition	±1/8 mm, type, size, etc.	±1/8 mm		yearly	250 km²	
Bottom Currents	>0.8 kt	±0.5 m/sec	12 hr			10% globe/yr
Bottom Gradient	>5	data sparse	annual			0.02 globe/yr
Bottom Loss	>3 dB	±3 dB	seasonal			0.2 globe/yr
Bottom Loss	>3 dB	±3 dB	2 yr			0.2 globe/yr
Bottom Reverb. (active)	±3 dB	±10 dB	12 hr			none
Bottom Roughness	>10% RMS roughness	DBDB .5	annual			0.05 globe/yr
Breaker Direction	>5 fluctuation	yes	6 hr	6 hr	individual beaches	remote sensing
Breaker Direction	>5 fluctuation	yes	3 hr			remote sensing

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Breaker Height	>1 m	±0.5 m	3 hr	3 hr	individual beaches	remote sensing
Breaker Interval	<15 sec.	±1 sec	3 hr	3 hr	individual beaches	remote sensing
Breaker Type	spill, plunge, collapse, surge	yes	3 hr			remote sensing
Breaker Type	spill, plunge, collapse, surge	±.25 m; ±.1 sec; ±.0.5		12 hr	50 km²	
Bright/Faint Star Positions	20 m/arc-sec.	10 m/arc-sec.	daily			yearly
Ceiling Height	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	2 hr			3 hr
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	3 hr			3 hr
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	daily			3 hr
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	1 hr			3 hr
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	30 min			3 hr
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft	8 hr			3 hr
Ceiling Layers	presence at 1000 ft intervals	±50 ft		8 hr	250 km²	
Ceiling Layers	presence at 1000 ft intervals	<5000 ft, ±100 ft; 5000-12000 ft, ±200 ft		8 hr	500 km²	

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Cloud Amount - Total	1/8 %					
Cloud Base	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Cloud Cover	>4/8 over OPAREA	yes	2 hr			yes
Cloud Cover	>4/8 over OPAREA	yes	1 hr			yes
Cloud Cover	>4/8 over OPAREA	yes	30 min			yes
Cloud Cover	>4/8 over OPAREA	yes	3 hr			yes
Cloud Cover	>4/8 over OPAREA	yes	4 hr			yes
Cloud Cover	>4/8 over OPAREA	yes		8 hr	250 km^2	
Cloud Top	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Cloud Type	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Cloud Type	char/alt	cloud type	continuous			3 hr
Clouds	TBD					
Commercial Towing	occurrence in OPAREA	±1 km; no database	daily			annual
Conductivity (sediments)	<20, >40 mho/m	yes	seasonal			0.01 globe/yr
Conductivity (sediments)	>40 mho/m	±1 k - 10 k mhos/cm	2 yr			0.01 globe/yr
Conductivity (water)	<20, >40 mho/m	yes	seasonal			0.20 globe/yr
Conductivity (water)	>40 mho/m	±1 k - 10 k mhos/cm	2 yr			0.2 globe/yr
Contrail	presence; potential	modeled	3 hr			remote
Contrails - 3 Engines/Persistence	1 unit (code)					
Contrails - Base	1000 feet					
Contrails - Top	1000 feet					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Convergence Zone	within 1 kyd	1 kyd at 1 CZ	6 hr			3 hr
Dew Point	>0.1 C depression	0.2 C, point source	30 min			3 hr
Dew Point	>0.1 C depression	0.2 C, point source	3 hr			3 hr
Dew Point	>0.2 C depression	0.2 C, point source	1 hr			3 hr
Dew Point	>0.2 C depression	0.2 C, point source	30 min			3 hr
Dew Point	>0.2 C depression	0.2 C, point source	3 hr			3 hr
Dew Point	<2 depression	0.2 C, point source		1 hr	50 km²	
Dew Point Depression	2 deg C					
Dew Point Profile	TBD					
Dredging Operations	within 5 km of flight path	±1 km	weekly			monthly
Dredging Operations	occurrence in OPAREA	±1 km	biannual			monthly
Dredging Operations	within 5 km of OPAREA	±1 km	biannual			monthly
Drilling Operations	occurrence in OPAREA	±10 m	yearly			monthly
Drilling Operations	within 5 km of flight path	±10 m	yearly			monthly
Ducting	height, thickness, persistence	modeling	3 hr			yes
Ducting	height, thickness, persistence	modeling	60 min			yes
Ducting	height, thickness, persistence	modeling	1 hr			yes

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Ducting	height, thickness, persistence, occurrence in OPAREA	modeling	6 hr	6 hr	50 km^2	yes
Dumping Operations	occurrence in OPAREA	±10 m - 2 km	biannual			biannual
Dumping Operations	within 5 km of IUSS sensor	±10 m - 2 km	biannual			biannual
E-Field	high e-field in OPAREA	±50 nV	30 days	30 days	OPAREA	0.01 globe/yr
E-Field	high e-field in OPAREA	±50 nV	2 yr			0.01 globe/yr
Endangered Species	presence in OPAREA	yes, variable	annual			yes, variable
Endangered Species	habitats and migration routes in OPAREA	yes, variable	annual			yes, variable
Extinction Coefficient	TBD					
Extreme Maximum Tidal Current Temp.	>15 C	no	12 hr			none
Extreme Maximum Tidal Current Temp.	>15 C	yes		24 hr	50 km^2	
Extreme Minimum Tidal Current Temp.	<15 C	no	12 hr			none
Extreme Minimum Tidal Current Temp.	<15 C	yes		24 hr	50 km^2	
Fog	visibility <1 nm	measured	2 hr			modeled for 12 hr
Fog	visibility <1 nm	measured	15 min			modeled for 12 hr
Fog	visibility <1 nm	measured	1 hr			modeled for 12 hr
Fog	visibility <1 nm	±100 m		1 hr	50 km^2	
Freezing Level	50 m					
Freezing Precipitation (H2O eqv)	0.1 in					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Freezing Precipitation Accumulation/Ice Accretion	0.1 in					
Frost Depth/Thaw Depth	1 in					
Geomagnetic Field	occurrence			continual	50 km^2	
Geopotential Height	10 m					
Hail Size	.2 in					
Haze	visibility <1 nm	no	2 hr	2 hr	50 km^2	none
High Seas Warning	1 meter					
High water	>2 ft diff. Between high/low water	±5 cm; 1 hr; 100 km^2	4 hr	4 hr	50 km^2	6 hr modeling
Humidity	>95%	±2% relative; point source	3 hr			3 hr modeling
Humidity	<20%, >90% relative	±2% relative; point source	12 hr			3 hr modeling
Humidity	>95%	±2% relative; point source	5 min			3 hr modeling
Humidity	<20%, >90% relative	±2% relative; point source	3 hr			3 hr modeling
Humidity	>95%	±2% relative; point source	30 min			3 hr modeling
Humidity	>95%	±2% relative; point source	4 hr			3 hr modeling
Humidity	>95%	±2% relative; point source	1 hr	1 hr	100 km^2	3 hr modeling
Humidity	>95%	±2%, point source		4 hr	50 km^2	
Humidity Profile	5-100%	±2%, point source		6 hr	50 km^2	
Ice Edge	1 km	1 km	weekly			daily remote
Ice Edge	1 km	1 km	bi-weekly			daily remote
Icing (sea surface)	pancake or denser	no automated, human observed	30 min			daily remote

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Icing (sea surface)	pancake or denser	no automated, human observed	3 hr			daily remote
Icing (sea surface)	pancake or denser	no automated, human observed	3 hr	3 hr	100 km²	daily remote
Icing (sea surface)	pancake or denser	no automated, human observed	daily			daily remote
Icing Base	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Icing Top	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Icing Type/Intensity	1 unit (code)					
Illumination	10(3)					
Inversion Layer Top Height AGL	50 feet					
Inversion Rate	lapse conditions	modeled w/o topography	1 hr			6 hr
Ionospheric Scintillation	occurrence in OPAREA	modeled	2 hr			3 hr
Ionospheric scintillation	occurrence in OPAREA	modeled	3 hr			3 hr
Ionospheric Scintillation	any significant occurrence in OPAREA	modeled	24 hr			3 hr
Lightning	within 10 km of OPAREA	forecast conditions favoring lightning	3 hr			no
Lightning	within 18 km of OPAREA	forecast conditions favoring lightning	3 hr			no

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Lightning	any occurrence	forecast conditions favoring lightning	1 hr			no
Lightning	within 20 km of flight path	forecast conditions favoring lightning	4 hr			no
Lightning	within 10 km of OPAREA	forecast conditions favoring lightning	4 hr			no
Lightning	1 (mile)					
Lightning	within 10 km of OPAREA	Forecast conditions favoring lightning		1 hr	50 km^2	
Liquid Water (vertical integration)	TBD					
Littoral Current Speed	1 m/s					
Littoral Current Speed	5 m/s					
Lunar Visibility	20 yd increments at 20 min.	<5 km: .4 km, 5-24 km: 1.6 km, >24 km: 8 km	30 min			yes
Lunar visibility	20 yd increments at 20 min.	<5 km: .4 km, 5-24 km: 1.6 km, >24 km: 8 km	3 hr			yes
Lunar visibility	20 yd increments at 20 min.	<5 km: .4 km, 5-24 km: 1.6 km, >24 km: 8 km	24 hr	24 hr	250 km^2	yes
Lunar Visibility	100 yd increments at 20 min.	<5 km: .4 km, 5-24 km: 1.6 km, >24 km: 8 km	12 hr			yes
Magnetic Anomalies	occurrence	±6 nT (rms)				no

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Marine Mammals	presence in OPAREA	seasonal aggregations	2 yr			seasonal
Marine Mammals	habitats and migration routes in OPAREA	seasonal aggregations	2 yr			seasonal
Marine Sanctuaries	occurrence in OPAREA	±10 m	2 yr			yes
Mean Daily Minimum Tidal Current Temp.	<15 C	no	12 hr			none
Mean Daily Minimum Tidal Current Temp.				24 hr	50 km^2	
Mean Daily Minimum Tidal Current Temp.				24 hr	150 km^2	
Moisture Profile	any type >0.5 in/hr	±2%, point source	3 hr			5 min
Moisture Profile	any type >0.5 in/hr	±2%, point source	1 hr			5 min
Moisture Profile	5-100%	±2%, point source	3 hr			5 min
Moisture Profile	5-100%	±2%, point source	5 min			5 min
Moisture Profile	any precipitation occurrence	±2%, point source	4 hr			5 min
Moisture Profile	5-100%	±2%, point source	2 hr			5 min
Moisture Profile	5-100%	±2%, point source	30 min			5 min
Moisture Profile	any type >0.5 in/hr	±2%, point source	4 hr			5 min
Moisture Profile	5-100%	±2%, point source	1 hr			5 min
Moisture Profile	5-100%	±2%, point source	6 hr			5 min
Moisture Profile	5-100%	±2%, point source	4 hr			5 min
Moisture Profile	2% humidity at 100 m increments	±0.25 in, point source		1 hr	50 km^2	
Moisture Profile	2% humidity at 100 m increments	±0.25 in, point source		1 hr	100 km^2	
Moon Phases	phase, ±10% illumination	modeled with global observations	24 hr			yes

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Moon Phases	1/10th increments	modeled with global observations	24 hr	24 hr	250 km^2	yes
Moon Rise/Set	±1 min	modeled	24 hr	24 hr	OPAREA	yes
Ordnance Test Ranges	locations within 100 yds of OPAREA	±10 m	2 yr			monthly
Precip. Noise	±10 dB	modeling	4 hr			40% accuracy
Precipitation Accumulation (H2O Equivalent)	TBD					
Precipitation Rate (H2O Equivalent)	.2 in/hr					
Precise Time	hr/min/sec	1 micro sec.	continual			yes
Present Weather	TBD					
QPF (6hr)	20%					
Radiation (background)						
Radiation - Longwave	TBD					
Radiation - Shortwave	TBD					
Radio (quasar positions)						
Rain (freezing)	occurrence in OPAREA	30% accuracy in modeling	30 min			3 hr
Rain (freezing)	occurrence in OPAREA	30% accuracy in modeling	1 hr			5 min
Rain (freezing)	occurrence in OPAREA	30% accuracy in modeling	1 hr			3 hr
Rain (freezing)	occurrence in OPAREA	.1 inches, point source		1 hr	50 km^2	
Rain (freezing)	occurrence in OPAREA	.1 inches, point source		1 hr	150 km^2; 0-40000 ft	
Rain Accumulation	0.1 in					
Rainfall Rate	>.5 in/hr	measured	2 hr			40% accuracy over 3 hr

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Rainfall Rate	>.5 in/hr	measured	4 hr			40% accuracy over 3 hr
Rainfall Rate	>.5 in/hr	measured	5 min			40% accuracy over 3 hr
Rainfall Rate	>.5 in/hr	measured	1 hr			40% accuracy over 3 hr
Rainfall Rate	>.5 in/hr	.1 inches, point source		1 hr	100 km^2	
Reefs	in OPAREA	±10 m	5 yr	5 yrs	50 km^2	yes
Refraction	occurrence in OPAREA	6 hr	yes			
Refraction	<5 km	6 hr	2 hr			
Refraction	Any Ducting in OPAREA	Dm/Dz trapping		3 hours	150 km^2	
Refractive Units (M)	nearest whole unit profiles	Dm/Dz trapping	3 hr			12 hr
Refractive Units (M)	profiles, nearest whole unit	Dm/Dz trapping		3 hours	150 km^2	
Relative Humidity	5 %					
Relative Humidity	20 %					
Relative Humidity (Average 1000/500mb)	20%					
Relative Humidity (UA)	TBD					
Relative Humidity Profile	TBD					
Salinity	>0.1 ppt	±0.1 ppt, if measured	24 hr			remote
Salinity	±0.1 ppt	±0.1 ppt		24 hr	OPAREA	
Sea Ice	within 50 km of OPAREA	±24 hr	24 hr	daily	50 km^2	remote
Sea Ice Noise	occurrence in OPAREA	±10 dB	4 hr			2 hr, modeled

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Sea Ice Thickness	.5 in					
Sea Level Pressure (SLP)	4 mb					
Sea Spray	best accuracy in size (mm); gm/cm^3 (vol.)	modeled	24 hr			4 hr
Sea Spray	>2 m	modeled	3 hr			4 hr
Sea Spray	gm/cm^3 size (mm) best accuracy	modeled	24 hr	24 hr	50 km^2	4 hr
Sea State (Wind Wave)	5 Degrees/.3 m					
Sea State (Wind Wave)	30 Deg/1 m					
Sea-Level Pressure	4 mb					
Shipping Density	distro./type/direct. Within 100 km of OPAREA	HITS database	4 hr			remotely sensed
Shipping Noise	AN >3 dB or units in OPAREA	modeled ±5 dB	12 hr			daily
Shipping Noise	occurrence in OPAREA	modeled ±5 dB	4 hr			daily
Snow Accumulation	0.5 in					
Snow Cover	>5 in	±2 in, 12 hrs, 80 km^2	1 hr	1 hr	10 km^2	12 hr
Snow Cover	>13 cm	±2 in, 12 hrs, 80 km^2		1 hr	10 km^2	
Snow Cover	>5 in	±2 in, 12 hrs, 80 km^2			10 km^2	
Snow Depth	2 in					
Snow Depth	.5 in					
Snow Depth (H20 equivalent)	.01 in					
Snow Drift Depth	6 in					
Snow Metamorphic State	TBD					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Snowfall Rate	>0.25 in/hr	0.5 in/hr	1 hr			3 hr, 30% confidence
Snowfall Rate	>0.25 in/hr	0.5 in/hr	2 hr			3 hr, 30% confidence
Snowfall Rate	>0.25 in/hr	0.5 in/hr	5 min			3 hr, 30% confidence
Snowfall Rate	>0.25 in/hr	0.5 in/hr	3 hr			3 hr, 30% confidence
Snowfall Rate	>.5 in/hr	±.01 in/hr; point source		1 hr	50 km^2	
Soil Moisture 0-10 cm	10%					
Soil Moisture 0-6 inches	5%					
Soil Moisture 10-30 cm	10%					
Soil Moisture 12-18 inches	5 %					
Soil Moisture 18-24 inches	5 %					
Soil Moisture 24-36 inches	5 %					
Soil Moisture 30-80 cm	10%					
Soil Moisture 6-12 inches	5%					
Soil Temperature	1 deg C					
Solar Flares	any occurrence	observed	3 hr			statistical model
Solar Flux	±5 x 10-5 WM-2	observed	24 hr			statistical model
Solar Radiation	any occurrence	observed	3 hr			statistical model
Solar Shadow Zones	any occurrence	observed	3 hr			statistical model
Sound Speed Profile	change >1 m/s w/in 5% of water depth (point source)	±3 m/s	12 hr			2 hr, modeled
Sound Speed Profile	±3 m/s	±10 dB	12 hr			2 hr, modeled
Sound Speed Profile	±1 m/s	±1 m/s measured	hourly			2 hr, modeled
Standing Water/Pooling	TBD					
Sub-Bottom Profiles	composition & roughness	measured and database	yearly			0.05 globe/yr

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Sub-Bottom Profiles	composition; vel. at ±10 m/s; density gm/cm^2	measured and database	yearly			0.05 globe/yr
Sun Spots	size/intensity	observed	3 hr			statistical model
Sun Spots	size/intensity	observed	12 hr			statistical model
Sunrise/Sunset	±1 min	observed and modeled	24 hr		OPAREA	
Surf (Height/Direction)	±0.5 m; >5 fluc.	±0.5 m	3 hr			6 hr
Surf (Height/Direction)	±0.5 m; >5 fluc.	±0.5 m; ±5 fluc.	3 hr			6 hr
Surf (Height/Direction/Type)	±1 ft/±5 /plunge,break, surge, spill	±0.5 m	6 hr			remote
Surf (Height/Direction/Type)	±0.5 m; >5 fluc.					
Surf Breaker Line	±0.5 m	modeled, not verifiable	3 hr			6 hr modeling
Surf Breaker Line	Distance from Shore	±1m, Near-Real Time for Requested Areas		3 hr	individual beaches	
Surf Direction	>5 fluctuation	Not verifiable, 6 hr, 100m-1km		3 hr	individual beaches	
Surf Height	±0.5 m	±0.5 m		3 hr	individual beaches	
Surf Height (Breakers)	1 ft					
Surf Plunge Point	distance from shore	modeled, not verifiable	3 hr	3 hr	individual beaches	6 hr modeling
Surf Zone Length	±20 m	±5 m, remote	3 hr			6 hr modeled
Surf Zone Length		±1m, Near-Real Time for Requested Areas		3 hr	individual beaches	
Surf Zone Width	±20 m	±1m, Near-Real Time for Requested Areas	3 hr	3 hr	individual beaches	6 hr modeled

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Surface Currents	>2 m/sec	measured, modeled with 50% confidence	24 hr			4 hr modeled
Surface Currents	>2 m/sec	measured, modeled with 50% confidence	8 hr			4 hr modeled
Surface Currents	>1.5 m/sec	measured, modeled with 50% confidence	12 hr			4 hr modeled
Surface Currents	>1.5 m/sec	±0.5 m/sec		12 hr	50 km^2	
Surface Film/Foam	concen. of surfactants	none	24 hr			none
Surface Reverb. (active)	>5 dB	modeled ±5 dB; measured ±1 dB	4 hr			3 hr
Surface Temperature	<32 F; >90 F; >100 F	remotely sensed	4 hr			continuous
Surface Temperature	<32 F; >90 F; >100 F	remotely sensed	12 hr			continuous
Surface Temperature	<32 F; >90 F; >100 F	remotely sensed	1 hr			continuous
Surface Temperature	2 deg C					
Surface Temperature, Inland Water Bodies	2 deg C					
Surface Temperature, Inland Water Bodies	1 deg C					
Surge	occurrence in OPAREA			6 hr	50 km^2	
Swell (height/direction)	>3.5 ft	modeled or remote	6 hr			modeled 4 hr; remote >12 hr
Swell (height/direction)	>1.5 m; >5 fluc.	modeled or remote	4 hr			modeled 4 hr; remote >12 hr

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Swell (height/direction)	sea state >1; >1 m; >5 fluc.	modeled or remote	4 hr			modeled 4 hr; remote >12 hr
Swell (height/direction)	>SS 3; >5 fluc.	modeled or remote	4 hr	4 hr	100 km²	modeled 4 hr; remote >12 hr
Swell Wave Direction	1 deg					
Swell Wave Height	1 meter					
Swell Wave Period	1 sec					
Swell Wave Period	1 s					
Temperature (air at surface)	<32 F; >90 F	±1 F, point source		3 hr	50 km²	
Temperature (air at surface)	<32 F; >90 F	±1 F, point source		2 hr	50 km²	
Temperature (air at water surface)	±1 C, >0 <140 F	±2 C	2 hr			no; COAMPS ±2 C at 60% confidence
Temperature (air at water surface)	<0 C.; >35 C	±2 C	2 hr			no; COAMPS ±2 C at 60% confidence
Temperature (air at water surface)	<32 F; >90 F	±2 C	2 hr			no; COAMPS ±2 C at 60% confidence
Temperature (air profile)	0.5 C at 100 m intervals	±1.0 C modeled at 70% confidence	1 min			12 hr modeled
Temperature (air profile)	0.5 C at 100 m intervals	±1.0 C modeled at 70% confidence	1 hr			12 hr modeled
Temperature (air profile)	0.5 C at 100 m intervals	±1.0 C modeled at 70% confidence	2 hr			12 hr modeled
Temperature (air profile)	0.5 C at 100 m intervals	±1.0 C modeled at 70% confidence	6 hr			12 hr modeled

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Temperature (air profile)	0.5 C at 100 m intervals	±1.0 C modeled at 70% confidence	4 hr			12 hr modeled
Temperature (air profile)	0.5 C at 100 m intervals	±0.5 C		4 hr	50 km^2	
Temperature (air profile)	0.5 C at 100 m intervals	±0.5 C		4 hr	100 km^2; 0-5000 ft	
Temperature (horiz. Var.)	modeled ±2 over water	±0.1 C measured; ±2 C modeled	2 hr			4 hr modeled
Temperature (horiz. Var.)	modeled ±2 over water	±0.1 C measured; ±2 C modeled	1 hr			4 hr modeled
Temperature (horiz. Var.)	2 F variations	±1 F, point source		3 hr	50 km^2	
Temperature (sea surface)	>15 C	0.2 C; point source	12 hr			4 hr modeled
Temperature (sea surface)	>15 C	0.2 C; point source	24 hr			4 hr modeled
Temperature (sea surface)	0.5 C at 100 m resolution	±.1 ; point source		24 hr	100 km^2	
Temperature (UA)	TBD					
Temperature (water column)	0.5 C at 100 m intervals 0-1000 m; 1.0 C at 20 m intervals	±1.0 C modeled at 60% confidence	4 hr			modeled 4 hr; 0.10 globe/yr
Temperature (water column)	0.5 C at 100 m intervals	±0.5 C		4 hr	50 km^2	
Temperature Sea Surface	1 deg C					
Temperature Sea Surface	2 deg C					
Temperature Wet Bulb Globe Index	1 deg C					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Thunderstorm Activity	within 10 km of OPAREA	observed/modeled	2 hr			12 hr modeled with 35% confidence
Thunderstorm Activity	within 5 km of OPAREA	observed/modeled	3 hr			12 hr modeled with 35% confidence
Thunderstorm Activity	occurrence in OPAREA	yes		2 hr	50 km^2	
Thunderstorms - Coverage	10 %					
Thunderstorms - Maximum Top	2500 feet					
Tidal Amplitude	>1 m in 0.1 m increments	±0.3 m, temporal as required	6 hr			4 hr modeling
Tidal Amplitude	>1 m in 0.1 m increments	±0.3 m, temporal as required	4 hr	4 hr	50 km^2	4 hr modeling
Tidal Currents	>1.5 m/sec	measured ±0.15 m/sec	6 hr			direct observation only
Tidal Currents	>1.5 m/sec	measured ±0.15 m/sec	12 hr	12 hr	20 km^2	direct observation only
Tidal Currents	>1.5 m/sec	measured ±0.15 m/sec	3 hr	3 hr	entire area of operation	direct observation only
Tidal Period	half hour accuracy	Yes	12 hr	12 hr	entire area of operation	6 hr
Tidal Period (times, phases, heights)	±5 min of peak phase (hi/low); ±0.5 m	direct observation	4 hr			variable; weather and asset site dependent
Tidal Surge	±5 ; ±1 m/s; ±0.5 m vert.	remote/direct observation	12 hr			no, >12 hrs repeatability
Time Interval Synchronization	1 micro/sec	GPS availability	continuous			continuous
Topography	±5 m	yes	once			annual
Topography	±5 m	yes	daily			annual

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Topography	±5 m	yes	24 hr			annual
Topography	100 m elev. at 30 m resolution	>1 m vert.		daily	50 km²	
Tops and Bases	<5000 ft in 100 ft intervals, 5-10000 ft in 500 ft intervals, >10000 ft in 1000ft intervals		3 hr			4 hr
Tornado	1 mile					
Total Precipitation	nearest 0.25 in.	0.1 in measured	2 hr			modeled ±1 in, 4 hr
Total Precipitation	>.2 in/hr	.01 inches, point source		2 hr	150 km²	
Trafficability						
Transmission Loss	±2 dB	±3 dB	12 hr			modeled continuously; measured tactically
Transmission Loss	high TL within 100 km² of OPAREA	±3 dB, Seasonal, 30-arc-minute grid	24 hr			modeled continuously; measured tactically
Transmission Loss	>2 dB	±3 dB	12 hr			modeled continuously; measured tactically
Transmission Loss	>2 dB per 10 km	±3 dB, Seasonal, 30-arc-minute grid	24 hr	24 hr	150 km²	modeled continuously; measured tactically

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Trawling Areas	occurrence in OPAREA	±2 to ±10 km	2 yr			remotely sensed
Trawling Areas	occurrence in OPAREA	±2 to ±10 km	annual			remotely sensed
Tropical Storms	25 miles					
Turbidity	in OPAREA	±10 km	annual			no
Turbidity	visibility <20 m horiz.	±10 m	24 hr			no
Turbulence Base	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Turbulence Intensity	1 unit (code)					
Turbulence Top	<= 1000 ft, ±100 ft; 5000-10000 ft, ±500 ft					
Type (precip.)	name any type occurring	measured 0.1 in.	2 hr			4 hr; modeled 1.0 in.
Type (precip.)	name any type occurring	yes		2 hr	50 km^2	
Vertical Velocities (Omega)	TBD					
Visibility	500 m					
Volume Reverb. (active)	>3 dB	±15 dB	12 hr			statistical/diurnal
Volume Reverb. (active)	occurrence in OPAREA	±15 dB	12 hr			statistical/diurnal
Vorticity (Absolute)	TBD					
Water Clarity	<1 m, <10 m, >20 m	±1 m observed	12 hr			remote, >12 hr repeatability
Water Clarity	<1 m, <10 m, >20 m	±2 dB per 5 sector		24 hr	50 km^2	

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Water Column Currents	>0.5 kt at 100 m intervals	±0.5 m/sec measured	12 hr	12 hr	50 km²	modeled seasonally; 10% globe/yr
Water Depth	±2 ft	±10 m (vert.); ±300 m (horiz.)	annual			0.05 globe/yr
Water Depth	±2 ft	±10 m (vert.); ±300 m (horiz.)	seasonal			0.05 globe/yr
Water Depth	<2.5 m contours	±10 m linear error	annual			0.05 globe/yr
Water Depth	<100 m depth	±10 m (vert.); ±300 m (horiz.)	annual			0.05 globe/yr
Water Depth	<8 ft depth	±10 m (vert.); ±300 m (horiz.)	annual			0.05 globe/yr
Water Depth	<2.5 m contours	±10 m (vert.); ±300 m (horiz.)	annual			0.05 globe/yr
Water Depth	100 m contours	±10 m (vert.); ±300 m (horiz.)	annual			0.05 globe/yr
Water Depth	±.5 psi	±.5 psi	12 hr			0.05 globe/yr
Water Depth	high bottom roughness in approach and landing zone	±10 m (vert.); ±300 m (horiz.)		1 mos	100 km²	
Water Droplet Size	TBD					
Water Quality	TBD					
Water Vapor	TBD					
Wave Direction	>5 fluc.	±5 fluc.	6 hr			4 hr modeling
Wave Direction	>5 fluc.	±5 fluc.	4 hr			4 hr modeling
Wave Direction	>5 fluc.	±5 fluc.	30 min			4 hr modeling
Wave Direction	>10 fluc.	±5 fluc.	4 hr			4 hr modeling
Wave Direction	>5 fluc.	±5 fluc.	3 hr			4 hr modeling
Wave Direction	>5 fluc.	±1 sea state; 3 fluc.		2 hr	50 km²	
Wave Direction	1 deg					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Wave Height	>SS 3	±0.5 m, 12 hr, 8-25 km	4 hr			4 hr modeled
Wave Height	>SS 3	±1 SS	3 hr			4 hr modeled
Wave Height	>SS 3	±1 SS	5 min			4 hr modeled
Wave Height	>SS 3	±1 SS	4 hr			4 hr modeled
Wave Height	1 meter					
Wave Height	>SS 3	±1 sea state; 3 fluc.		2 hr	50 km²	
Wave Noise	SS >3	±10 dB	4 hr			4 hr measured
Wave Period	>8 sec., ±1 sec.	remote measured	30 min			remotely, >12 hr repeatability
Wave Period	>8 sec., ±1 sec.	remote measured	12 hr			remotely, >12 hr repeatability
Wave Period	>8 sec., ±1 sec.	remote measured	3 hr			remotely, >12 hr repeatability
Wave Period	1 sec					
Wave Period	>8 sec.	not verifiable		1 hr	25 km²	
Wind (flight level) (direction/speed)	>10 fluc.; >40 kt	5 , 5 kt, modeled	3 hr			6 hr
Wind (flight level) (direction/speed)	>10 fluc.; >40 kt	5 , 5 kt, modeled	1 hr			6 hr
Wind (flight level) (direction/speed)	>10 fluc.; >40 kt	5 , 20 knots		1 hr	50 km²	
Wind (temperature/ direction - profile)	TBD					
Wind (U/V)	5 Deg/3 mps					
Wind (U/V)	10 Deg/5 mps					
Wind (U/V)	5 Deg/5 mps					
Wind (U/V)	5 Deg/10 mps					
Wind (U/V)	5 Deg/13 mps					

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Wind Aloft (direction/ speed)	>10 fluc.; >40 kt	5 , 5 kt, modeled	3 hr			6 hr
Wind Aloft (direction/ speed)	>10 fluc.; >40 kt	5 , 9 kph, point source		1 hr	50 km²	
Wind Gust Speed	1 m/s					
Wind Shear	occurrence	measured tactically; ±20% speed; ±5 fluc.	6 hr			6 hr
Wind Shear	>20 kt; >10 fluc.	±20% speed		15 min	50 km²	
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±5 kt; ±5 fluc.	6 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.	±5 kt; ±5 fluc.	6 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >1 kt	±5 kt; ±5 fluc.	2 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±5 kt; ±5 fluc.	4 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.	±5 kt; ±5 fluc.	4 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	sea state >1; >5 fluc.; >10 kph	±5 kt; ±5 fluc.	4 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >1 kt	±5 kt; ±5 fluc.	1 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >1 kt	±5 kt; ±5 fluc.	4 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±5 kt; ±5 fluc.	1 hr			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±5 kt; ±5 fluc.	1 min			modeled 6 hr; 50% confidence
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±5 kt; ±5 fluc.	2 hr			modeled 6 hr; 50% confidence

Table 3.1. Joint Requirements Table, continued.

Element	Critical Value/Threshold	Current Capability	Update Requirement	Update Capability	Refresh Requirement	Spatial Coverage
Wind Surface (direction/ speed)	>10 fluc.; >20 kt, >63 kt	±1 , point source		4 hr	10 km^2	
Wind Warning	10 m/s					
Wind Warning	5 m/s					
Windchill	1 deg C					

Table 3.2. Horizontal Scale Table (**H1**).

H1	**Horizontall Domain**
1	MICROSCALE (<1 km)
2	MESOSCALE (10 km - <400 km)
3	MICRO/MESOSCALE (<1 km - <=400 km)
4	SYNOPTIC SCALE (>400 km)
5	MESOSCALE II (1km - 10km)

Table 3.3. Horizontal Land/Ocean Table (**H2**).

H2	**Horizontal2 Domain**
1	COMBINE (2,3,4,5,6)
2	LAND
3	LAND/LITTORAL
4	OPEN OCEAN
5	LITTORAL/OPEN OCEAN
6	POLAR

Table 3.4. Vertical Scale Table (**V**).

V	**Vertical Domain**
1	SURFACE
2	SFC/UA (PROFILE) (LAND OR OCEAN) (SFC > 1000m)
3	UPPER ATMOSPHERE (LAND OR OCEAN) (>1000m)
4	BOUNDARY LAYER (LAND OR OCEAN) (SFC - 1000m)
6	OCEAN BOTTOM
7	OCEAN DEEP WATER
8	OCEANIC MIXED LAYER
9	OCEAN SURFACE/DEEP WATER (PROFILE)

Table 3.5. Measurement Duration Table (**T1**).

T1	**Time1 Domain**
1	HIGH AMOUNT OF TIME (>1 min.)
2	LOW AMOUNT OF TIME (<1 sec.)
3	MEDIUM AMOUNT OF TIME (1 sec. - 1 min.)

Table 3.6. Measurement Refresh Table (**T2**).

T2	**Time2 Domain**
1	HIGH REFRESH RATE (<1 hr.)
2	LOW REFRESH RATE (> diurnal)
3	MED REFRESH RATE (1 hr. - diurnal)

Table 3.7. Unperturbed Air Stream Requirement/Delivery Potential Table (**UAS**).

UAS	**UAS required/provided**
1	YES
2	NO

Table 3.8. Joint METOC Element Table.

Joint METOC Element	**H1**	**H2**	**V**	**T1**	**T2**	**UAS**
Absolute Humidity (Boundary Layer)	3	1	4	2	3	1
Aerosols (Boundary Layer)	3	1	4	1	3	1
Aerosols (profile)	3	1	2	1	3	1
Aerosols (UA)	2	1	3	1	3	1
Ambient Noise	3	5	9	3	3	2
Anchorages	1	3	1	2	2	2
Aquaculture Areas	1	3	9	3	2	2
Archeological Sites/Wrecks	1	5	6	1	2	2
Atmospheric Contaminants (Boundary Layer)	3	1	4	1	3	1
Atmospheric Contaminants (profile)	1	1	2	1	1	1
Atmospheric Contaminants (UA)	2	1	3	1	3	1
Atmospheric Transmissivity (Boundary Layer)	3	1	4	1	3	2
Atmospheric Transmissivity (profile)	3	1	2	1	1	2
Atmospheric Transmissivity (UA)	2	1	3	1	2	2
Atmospheric Visual Range (Boundary Layer)	3	1	4	1	3	2
Atmospheric Visual Range (profile)	3	1	2	1	1	2
Atmospheric Visual Range (UA)	2	1	3	1	2	2
Barometric Pressure (Boundary Layer)	3	1	4	2	3	1
Barometric Pressure (profile)	1	1	2	2	1	1
Barometric Pressure (surface)	1	1	1	2	3	1
Barometric Pressure (UA)	4	1	3	3	2	1
Beach Characteristics	1	3	1	1	2	2
Beach Slope	1	3	1	3	3	2
B-Field	4	1	2	1	2	2
Biological Noise	3	5	9	3	3	2

Table 3.8. Joint METOC Element Table, continued.

Joint METOC Element	**H1**	**H2**	**V**	**T1**	**T2**	**UAS**
Bioluminescence	1	5	8	2	3	2
Bottom Composition	3	5	6	1	2	2
Bottom Currents	3	5	6	1	2	2
Bottom Gradient	3	5	6	1	2	2
Bottom Loss	2	5	6	1	2	2
Bottom Reverb. (active)	2	5	6	1	2	2
Bottom Roughness	3	5	6	1	2	2
Breaker Direction	1	3	1	3	3	2
Breaker Height	1	3	1	3	3	2
Breaker Interval	1	3	1	3	3	2
Breaker Type	1	3	1	3	3	2
Ceiling Height	1	1	2	2	1	2
Ceiling Layers	3	1	2	3	1	2
Cloud Amount - Total	3	1	2	3	3	2
Cloud Amount - Total (Boundary Layer)	3	1	4	3	3	2
Cloud Base	1	1	2	2	1	2
Cloud Top	1	1	2	2	1	2
Cloud Type	3	1	2	3	3	2
Commercial Towing	3	5	1	3	1	2
Conductivity (sediments)	3	5	1	1	2	2
Conductivity (water)	1	5	9	3	3	2
Contrail	3	1	3	2	3	2
Contrails - 3 Engines/Persistence	3	1	3	2	3	2
Contrails - Base	3	1	3	3	3	2
Contrails - Top	3	1	3	3	3	2
Convergence Zone	3	4	9	3	3	2
Dew Point	1	1	1	2	3	1
Dew Point Depression	1	1	1	2	3	1
Dew Point Profile (Boundary Layer)	1	1	2	3	3	1
Dredging Operations	1	3	8	3	3	2
Drilling Operations	1	5	9	3	2	2
Ducting	3	1	2	3	3	1
Ducting (Boundary Layer)	3	1	4	3	3	1
Dumping Operations	1	3	1	3	3	2
E-Field	3	1	2	3	3	2
Endangered Species	4	1	1	1	2	2
Extinction Coefficient	3	1	2	1	3	1
Extreme Maximum Tidal Current Temp.	1	3	1	1	3	2
Extreme Minimum Tidal Current Temp.	1	3	1	1	3	2

Table 3.8. Joint METOC Element Table, continued.

Joint METOC Element	H1	H2	V	T1	T2	UAS
Freezing Level	3	1	2	3	2	1
Freezing Precipitation (H2O eqv)	3	1	1	3	1	2
Freezing Precipitation Accumulation/Ice Accretion	3	1	1	3	3	2
Frost Depth/Thaw Depth	3	2	1	1	2	2
Hail Size	1	1	1	3	1	2
High water	1	2	1	1	3	2
Humidity	3	1	2	2	3	1
Humidity (profile, Boundary Layer)	1	1	4	3	3	1
Ice Accumulation	1	1	2	3	3	2
Ice Edge	3	6	1	1	2	2
Icing (sea surface)	3	5	1	1	3	2
Icing Base	3	1	2	3	3	2
Icing Top	3	1	2	3	3	2
Icing Type/Intensity	3	1	2	3	3	2
Imagery, Visual	1	3	1	3	2	2
Inversion Layer Top Height AGL (Boundary Layer)	3	1	4	3	3	1
Inversion Rate	3	1	4	3	3	2
Lightning	3	1	2	2	1	2
Liquid Water (vertical integration)	3	1	2	3	3	1
Littoral Current Speed	3	3	9	1	2	2
Magnetic Anomalies	1	4	1	2	1	2
Marine Mammals	3	5	9	1	2	2
Mean Daily Minimum Tidal Current Temp.	1	3	1	3	3	2
Precip. Noise	3	5	1	2	1	2
Precipitation Accumulation (H2O Equivalent)	1	1	1	3	1	1
Precipitation Rate (H2O Equivalent)	1	1	1	1	1	1
Precipitation Rate (H2O Equivalent) (Boundary Layer)	1	1	1	1	1	1
Radiation - Longwave	3	1	1	1	2	2
Radiation - Longwave (Boundary Layer)	3	1	4	1	2	2
Radiation - Shortwave	3	1	1	1	2	2
Radiation - Shortwave (Boundary Layer)	3	1	4	1	2	2
Radiation (background)	3	1	1	1	2	2
Radiation (background) (Boundary layer)	3	1	4	1	2	2
Reefs	1	3	9	3	2	2
Refraction	3	1	2	3	3	1
Refractive Units (M)	3	1	2	3	3	1
Relative Humidity (Average 1000/500mb)	3	1	2	2	3	1
Relative Humidity (Boundary Layer)	3	1	4	3	3	1
Relative Humidity (UA)	3	1	3	2	3	1

Table 3.8. Joint METOC Element Table, continued.

Joint METOC Element	H1	H2	V	T1	T2	UAS
Salinity	3	5	9	3	2	2
Sea Ice	3	6	1	3	2	2
Sea Ice Noise	3	6	9	3	1	2
Sea Ice Thickness	3	6	1	1	2	2
Sea Level Pressure (SLP)	3	1	1	2	3	1
Sea Spray (Boundary Layer)	1	4	4	3	3	2
Sea State (Wind Wave)	3	5	1	3	3	2
Shipping Density	3	5	1	1	2	2
Shipping Noise	3	5	9	1	2	2
Snow Accumulation	3	2	1	1	3	2
Snow Cover	3	2	1	3	3	2
Snow Depth	3	2	1	1	3	2
Snow Depth (H20 equivalent)	3	2	1	1	3	2
Snow Drift Depth	3	2	1	1	3	2
Snow Metamorphic State	3	2	1	1	3	2
Snowfall Rate (Boundary Layer)	3	2	1	3	3	1
Soil Moisture	3	2	1	3	2	2
Soil Temperature	3	2	1	2	3	2
Sound Speed Profile	1	5	9	3	3	2
Standing Water/Pooling	1	2	1	1	3	2
Sub-Bottom Profiles	3	5	6	1	2	2
Surf (Height/Direction)	1	3	1	3	3	2
Surf (Height/Direction/Type)	1	3	1	1	3	2
Surf Breaker Line	1	3	1	3	3	2
Surf Direction	1	3	1	2	3	2
Surf Height	1	3	1	3	3	2
Surf Height (Breakers)	1	3	1	3	3	2
Surf Plunge Point	1	3	1	3	3	2
Surf Zone Length	1	3	1	3	3	2
Surf Zone Width	1	3	1	3	3	2
Surface Currents	3	5	1	1	2	2
Surface Film/Foam	1	3	1	2	3	2
Surface Reverb. (active)	3	4	9	1	3	2
Surface Temperature, Inland Water Bodies	1	2	1	3	3	2
Surface Temperature, Ocean	3	5	1	3	3	2
Surge	1	3	1	3	1	2
Swell (height/direction)	3	5	1	3	3	2
Swell Wave Direction	3	5	1	3	3	2
Swell Wave Height	3	5	1	3	3	2

Table 3.8. Joint METOC Element Table, continued.

Joint METOC Element	H1	H2	V	T1	T2	UAS
Swell Wave Period	3	5	1	3	3	2
Temperature (air at surface)	3	2	1	2	3	1
Temperature (air at water surface)	3	5	1	2	3	1
Temperature (air profile)	3	1	2	2	3	1
Temperature (air profile) (Boundary Layer)	3	1	4	2	3	1
Temperature (horiz. Var.)	3	1	1	2	3	1
Temperature (UA)	3	1	3	2	3	1
Temperature (water column)	1	5	9	3	3	2
Temperature Wet Bulb Globe Index	3	1	2	2	3	1
Thunderstorm Activity	3	1	2	3	1	2
Thunderstorms - Coverage	3	2	2	3	1	2
Thunderstorms - Maximum Top	3	2	2	3	1	2
Tidal Amplitude	3	3	1	3	3	2
Tidal Currents	3	3	1	3	3	2
Tidal Period	3	3	1	3	5	2
Tidal Period (times, phases, heights)	3	3	1	1	3	2
Tidal Surge	3	3	1	3	1	2
Tornado	1	1	2	2	1	2
Trafficability	3	2	1	1	3	2
Transmission Loss	3	5	9	1	3	2
Trawling Areas	1	5	1	3	3	2
Tropical Storms	4	1	2	1	1	2
Turbulence Base	1	1	3	1	1	1
Turbulence Base (Boundary Layer)	1	1	2	1	1	1
Turbulence Intensity	1	1	2	1	1	1
Turbulence Intensity (Boundary Layer)	1	1	4	1	1	1
Turbulence Top	1	1	2	1	1	1
Turbulence Top (Boundary Layer)	1	1	4	1	1	1
Vertical Velocities (Omega)	3	1	2	1	3	1
Visibility	3	1	4	1	3	2
Volume Reverb. (active)	3	5	9	1	2	2
Water Clarity	1	3	8	3	1	2
Water Column Currents	1	5	8	1	2	2
Water Depth	3	1	9	3	2	2
Water Droplet Size	3	1	2	3	3	2
Water Quality	1	2	1	1	1	2
Wave Direction	3	5	1	3	3	2
Wave Height	3	5	1	3	3	2
Wave Noise	3	5	1	3	3	2

Table 3.8. Joint METOC Element Table, continued.

Joint METOC Element	**H1**	**H2**	**V**	**T1**	**T2**	**UAS**
Wave Period	3	5	1	3	3	2
Wind (Boundary Layer)	3	1	4	3	3	2
Wind (flight level) (direction/speed)	3	1	3	3	3	2
Wind Surface (direction/speed)	3	1	1	2	3	2

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments.

COUNTRY	**NAME**	**H1**	**H2**	**V**	**T1**	**T2**	**UAS**
AUSTRALIA	JINDIVIK Mk4A	4	1	2	2	3	1
AUSTRIA	CAMCOPTER	3	3	2	1	3	2
BELGIUM	EPERVIER	3	3	2	2	3	1
BELGIUM	ULTIMA 14/255	3	1	4	2	3	1
BRAZIL	K1 AM	2	3	2	2	3	1
BRAZIL	AM 03089	2	1	3	2	3	1
BULGARIA	PELICAN AM4/E	3	2	2	2	3	1
BULGARIA	YASTREB-2MB	3	2	2	2	3	1
BULGARIA	YASTREB-2S	3	2	2	2	3	1
CANADA	MILKCAN						
CANADA	POP-UP HELICOPTER	1	2	1	3	1	1
CANADA	CL-227 SENTINEL	3	1	2	3	1	2
CANADA	CL-327 GUARDIAN	3	1	2	1	1	2
CANADA	CL-427	3	1	2	1	1	2
CANADA	CL-89	3	2	2	2	3	1
CANADA	HIND-D	5	1	2	1	3	1
CANADA	HOKUM-X	3	3	2	1	3	2
CANADA	ROBOT 9	5	2	2	2	3	1
CANADA	ROBOT-X	3	1	2	2	3	1
CANADA	TATS 102/103	3	3	2	2	3	1
CANADA	VAMPIRE	4	1	2	2	3	1
CANADA	VINDICATOR II	2	3	2	2	3	1
CANADA	BLACK BRANT BB10 MOD 1	4	1	3	2	2	1
CANADA	BLACK BRANT BB5	4	1	3	2	2	1
CANADA	BLACK BRANT BB9 MOD 1	4	1	3	2	2	1
CANADA	EXCALIBUR 1B	2	3	3	2	2	1
CANADA	LEAP	5	3	4	2	3	1
CANADA	TATS 1	5	3	4	2	3	1
CANADA	TATS 50	5	1	4	2	3	1
CHINA	ASN-104	3	3	2	2	3	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
CHINA	ASN-105	3	3	2	2	3	1
CHINA	ASN-12	3	3	2	2	3	1
CHINA	ASN-206	3	3	2	2	3	1
CHINA	ASN-7	3	3	2	2	3	1
CHINA	ASN-9	3	1	2	2	3	1
CHINA	BJ7104	3	3	2	2	3	1
CHINA	BJ7104 B-2B	3	3	2	2	3	1
CHINA	CHANG KONG CK1C	4	1	2	2	3	1
CHINA	CHANG KONG CK1E	4	1	2	2	3	1
CHINA	D-4 RD	3	3	2	2	3	1
CHINA	SHEN ZHOU-1	5	2	2	2	3	1
CHINA	SHEN ZHOU-2	5	2	2	2	3	1
CHINA	TYPE 130/TQ-4 FIREFLY	3	3	2	2	3	1
CHINA	CHANG HONG 1	4	1	3	2	3	1
CHINA	FK-11	3	2	4	2	3	1
CHINA	FK-12	3	2	4	2	3	1
CHINA	NRIST YK-7	5	2	4	2	3	1
CHINA	OBSERVER 1	5	1	4	2	3	1
CZECH REPUBLIC	SOJKA III	3	3	2	2	3	1
EGYPT	TN-1B	5	2	2	2	3	1
FINLAND	AT 85	3	1	4	2	3	1
FINLAND	AT 97	3	1	4	2	3	1
FRANCE	C22L	4	1	2	2	3	1
FRANCE	CHACAL	4	1	2	2	3	1
FRANCE	CRECERELLE	3	3	2	2	1	1
FRANCE	CRECERELLE-SCALA	3	3	2	2	1	1
FRANCE	DRAGON	3	3	2	2	1	1
FRANCE	DRAGON FLY HELIOT	3	1	2	1	3	2
FRANCE	E-C 22	4	1	2	2	3	1
FRANCE	ECLIPSE T2	3	1	2	2	2	1
FRANCE	FOX AT1	3	1	2	2	3	1
FRANCE	FOX AT2	3	1	2	2	3	1
FRANCE	FOX TS3	3	3	2	2	3	1
FRANCE	FOX TX	3	3	2	2	1	1
FRANCE	MARULA	4	1	2	2	3	1
FRANCE	S-MART	3	3	2	2	1	1
FRANCE	SPERWER, UGGLAN	3	3	2	2	1	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
FRANCE	VIGILANT F2000	3	1	2	1	3	2
FRANCE	BOUCANIERE	5	3	4	2	3	1
FRANCE	HUSSARD 2	5	2	4	2	3	1
FRANCE	MART MK II	3	3	4	2	3	1
GERMANY	MK-105 FLASH	3	3		2	3	1
GERMANY	MK-106 HIT C	3	3		2	3	1
GERMANY	SK10						
GERMANY	SK6						
GERMANY	DAR	3	3	2	2	3	1
GERMANY	SEAMOS LV	3	1	2	1	3	2
GERMANY	TAIFUN (ATTACK) AND MUCKE (ECM)	3	3	2	2	3	1
GERMANY	LOTTE 3	3	3	4	2	3	1
GREECE	IRIS	3	2	1	2	3	1
GREECE	ALKYON	3	3	2	2	3	1
GREECE	F-16 SCALE TARGET	5	1	2	2	3	1
GREECE	NEARCHOS	3	3	2	2	1	1
INDIA	NISHANT	3	3		2	3	1
INDIA	KAPOTHAKA	3	2	2	2	3	1
INDIA	LAKSHYA	3	3	2	2	3	1
INDIA	ULKA	3	1	2	2	3	1
INTER-NATIONAL	BQM-155A E-Hunter	3	1	2	2	1	1
INTER-NATIONAL	BQM-155A Hunter	3	1	2	2	1	1
INTER-NATIONAL	BREVEL	3	3	2	2	3	1
INTER-NATIONAL	RQ-2A PIONEER OPTION 2+	3	1	2	2	3	1
INTER-NATIONAL	SIVA	3	3	2	2	1	1
INTER-NATIONAL	CL-289	3	3	4	2	3	1
INTER-NATIONAL	ROBOCOPTER 300	3	3	4	1	3	2
IRAQ	KFIR-C2 SCALE TARGET						
ISRAEL	CROW	3	3	2	2	1	1
ISRAEL	DARTER	3	3	2	2	1	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
ISRAEL	DELILAH	3	1	2	2	3	1
ISRAEL	EYE VIEW A	3	3	2	2	1	1
ISRAEL	EYE VIEW B	3	3	2	2	1	1
ISRAEL	FIREBIRD 2001	3	3	2	2	1	1
ISRAEL	FIREFLY	3	3	2	2	3	1
ISRAEL	HARPY	3	3	2	2	3	1
ISRAEL	HAWK	3	3	2	2	1	1
ISRAEL	HERMES 1500	3	2	2	2	1	1
ISRAEL	HERMES 450	3	1	2	2	1	1
ISRAEL	HERMES 450S	3	1	2	2	1	1
ISRAEL	HERON	4	1	2	2	1	1
ISRAEL	HERON SHORT WING	4	1	2	2	1	1
ISRAEL	HERON TURBOPROP	4	1	2	2	1	1
ISRAEL	ITALD	3	1	2	2	3	1
ISRAEL	MICRO-V	3	3	2	2	3	1
ISRAEL	SAMSON	3	3	2	2	3	1
ISRAEL	SCOUT	3	3	2	2	1	1
ISRAEL	SEARCHER	3	1	2	2	1	1
ISRAEL	SNOOPER	5	3	2	2	3	1
ISRAEL	TALD	3	1	2	2	3	1
ISRAEL	VANGUARD	3	3	2	2	1	1
ISRAEL	COLIBRI 62A	3	3	4	2	3	1
ISRAEL	COLIBRI 62B	3	3	4	2	3	1
ISRAEL	MIG-27 SCALE TARGET	5	2	4	2	3	1
ISRAEL	TM-105 EDO	5	1	4	2	3	1
ITALY	MIRACH 10	3	1	2	2	3	1
ITALY	MIRACH 100	3	1	2	2	3	1
ITALY	MIRACH 100 RECCE	4	1	2	2	3	1
ITALY	MIRACH 150	3	1	2	2	3	1
ITALY	MIRACH 26	3	1	2	2	1	1
ITALY	MIRACH 70	3	1	2	2	3	1
JAPAN	J/AQM-1	3	1	2	2	3	1
JAPAN	MAMBOW 4	5	2	4	2	3	1
JAPAN	R-50	1	2	4	1	3	1
JAPAN	R-MAX	1	2	4	1	3	1
JAPAN	RPH-2	3	3	4	1	3	2
NORWAY	DOLPINE	3	1	2	2	3	1
NORWAY	PRS DELTA	3	1	2	2	3	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
PAKISTAN	ABABEEL	5	1	4	2	3	1
PAKISTAN	BAAZ	5	2	4	2	3	1
PORTUGAL	ARMOR X7	3	1	2	2	1	1
ROMANIA	ATS 01-01	3	2	2	2	3	1
RUSSIA	3M20M3	3	3	2	2	3	1
RUSSIA	DAN	3	3	2	2	3	1
RUSSIA	E85	3	3	2	2	3	1
RUSSIA	E95	5	3	2	2	3	1
RUSSIA	KA-137	4	1	2	1	3	2
RUSSIA	KA-37	5	3	2	1	3	1
RUSSIA	R90	3	1	2	2	3	1
RUSSIA	SHMEL-1	3	2	2	2	3	1
RUSSIA	SHMEL-2	3	3	2	2	3	1
RUSSIA	TU-141 STRIZH	4	1	2	2	1	1
RUSSIA	TU-143, -243, -300	3	2	2	2	3	1
RUSSIA	RD-1.5	3	2	4	2	3	1
SOUTH AFRICA	LARK	3	1		2	3	1
SOUTH AFRICA	BUZZARD 3	3	3	2	2	3	1
SOUTH AFRICA	RPV-2 SEEKER	3	3	2	2	1	1
SOUTH AFRICA	SKUA	3	1	2	2	3	1
SOUTH AFRICA	VULTURE	3	3	2	2	3	1
SOUTH AFRICA	LOCATS	5	2	4	2	3	1
SOUTH KOREA	ARCH-50	5	2	4	1	3	1
SPAIN	ALO	3	3	2	2	3	1
SPAIN	ALBA	5	2	4	2	3	1
SWEDEN	MIDGET RPG	3	1	2	1	3	2
SWEDEN	RIPAN	1	1	4	2	3	1
SWITZER-LAND	ADS 95 RANGER	3	3	2	2	3	1
SWITZER-LAND	TOPAZ	5	2	2	2	3	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
TAIWAN	T-10 & T-20	5	1	2	2	3	1
TAIWAN	THUNDER TIGER T-60	3	3	2	2	3	1
TURKEY	TAI TARGET DRONE	3	2	2	2	3	1
TURKEY	UAV-X1	4	3	2	2	1	1
UK	ARIEL						
UK	HISAT						
UK	MINI						
UK	AGT-30, -40	3	2	2	2	3	1
UK	BTT-1 IMP	5	1	2	2	3	1
UK	BTT-3 BANSHEE	3	1	2	2	3	1
UK	FALCONET	5	3	2	3	3	1
UK	MGT-15	5	2	2	2	3	1
UK	MGT-20	5	2	2	2	3	1
UK	MMT-100	3	3	2	2	3	1
UK	PETREL	3	1	2	2	3	1
UK	PHANTOM	3	3	2	2	3	1
UK	PHOENIX	3	3	2	2	3	1
UK	RAVEN	3	3	2	2	3	1
UK	SAGT-50, -60	3	3	2	2	3	1
UK	SKEET	5	1	2	2	3	1
UK	SPECTRE	3	3	2	2	3	1
UK	MRTT	3	1	3	2	3	1
UK	DRAGONFLY	5	1	4	2	3	1
UK	GT-10	5	1	4	3	3	1
UK	PIG SERIES	5	3	4	2	3	1
USA	AN/ALE-50						
USA	BLAZER						
USA	FLYRT						
USA	HUTTS						
USA	IRTT						
USA	RADAR TOW TARGETS (MEGGITT)						
USA	SGT-20						
USA	TDK-39						
USA	TDU-34/A						
USA	TLX-1						
USA	23F & 60F	5	2	2	1	3	1
USA	32M & 71M	3	1	2	2	1	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
USA	ACRW (AIRCRAFT WITH CIRCULAR ROTATING WING)	3	1	2	2	3	1
USA	AEROSONDE	4	1	2	3	1	1
USA	ALTUS	4	1	2	2	1	1
USA	APEX	3	3	2	2	3	1
USA	ARROW	4	1	2	2	1	1
USA	AURA	4	1	2	2	1	1
USA	BQM-34 FIREBEE I	4	1	2	2	3	1
USA	BQM-74C RECCE	4	1	2	2	3	1
USA	CANARD/ROTOR WING	4	1	2	1	3	2
USA	CENTURION	3	3	2	2	3	1
USA	CHUKAR BQM-74/MQM-74	4	1	2	2	3	1
USA	CYPHER	3	3	2	1	3	1
USA	DRAGON	3	1	2	2	3	1
USA	EAGLE EYE	3	1	2	1	1	1
USA	EXDRONE	3	1	2	2	3	1
USA	GNAT 750	4	1	2	2	1	1
USA	HORNET	4	3	2	2	1	1
USA	I-GNAT	4	1	2	2	1	1
USA	MALD	4	1	2	2	3	1
USA	MODEL 410	4	1	2	2	1	1
USA	MQM-107 STREAKER	3	3	2	2	3	1
USA	OUTRIDER	3	1	2	2	3	1
USA	PARADACTYL AND PARAKEET	3	3	2	2	3	1
USA	PATHFINDER	3	1	2	2	1	1
USA	PENETRATOR-T	4	3	2	2	3	1
USA	PERSEUS A & B	4	3	2	2	1	1
USA	PROWLER	3	3	2	2	1	1
USA	QF-106	4	3	2	2	1	1
USA	QF-4	4	1	2	2	3	1
USA	QMIG-21	4	3	2	2	3	1
USA	R4E SKYEYE	3	3	2	2	1	1
USA	RDAE BTT & MQM-33/36	3	1	2	2	3	1
USA	RPB-35 WASP	3	3	2	2	3	1
USA	RQ-1A PREDATOR	4	1	2	2	1	1
USA	RQ-3A DARKSTAR (TIER III-)	4	1	2	2	1	1
USA	RQ-4A GLOBAL HAWK (TIER II+)	4	1	2	2	1	1

Table 3.9. Selected data from the RPA Table; spatial, temporal and air stream assignments, continued.

COUNTRY	NAME	H1	H2	V	T1	T2	UAS
USA	SCALE TARGETS (E.G. A-7, A-10, MIG-27, SU-17, ETC.)	3	1	2	2	3	1
USA	SCALE TARGETS (RS SYSTEMS)	5	1	2	2	3	1
USA	SCARAB	4	1	2	2	1	1
USA	SEA FERRET	4	1	2	2	3	1
USA	SHADOW	4	1	2	2	1	1
USA	SHADOW 200	3	3	2	2	1	1
USA	SHADOW 600	3	1	2	2	1	1
USA	STARBIRD	3	3	2	2	1	1
USA	STF-9	3	1	2	1	3	1
USA	STM5B(1) SENTRY	3	3	2	2	1	1
USA	SWALLOW	3	3	2	2	3	1
USA	TERN	3	3	2	2	3	1
USA	THESEUS	4	1	2	2	1	1
USA	TILT-BODY	3	3	2	3	3	1
USA	TRUCK	3	3	2	2	3	1
USA	VIXEN AND HELLFOX	3	1	2	2	3	1
USA	W570A	4	1	2	2	1	1
USA	X-36	3	3	2	2	3	1
USA	AQM-37	3	1	3	2	3	1
USA	TMX & TRX-12	3	1	3	2	3	1
USA	DRAGONFLY DP4	3	2	4	1	3	2
USA	JAVELIN	5	1	4	2	3	1
USA	SENDER	3	3	4	2	3	1
YUGO-SLAVIA	VBL-2000	4	1	2	2	1	1
YUGO-SLAVIA	PRM-200	3	3	3	2	3	1
YUGO-SLAVIA	M-2M	3	3	4	2	3	1

Table 3.10. SQL Code linking RPA and Joint METOC Element Tables with assignments (Tables 3.8 and 3.9).

```
SELECT [tbl1Joint Element].Element, [tblUAV (flat file)].COUNTRY, [tblUAV (flat
file)].NAME, [tblUAV (flat file)].TYPE
FROM [tbl1Joint Element], [tblUAV (flat file)]
```

Table 3.10. SQL Code linking RPA and Joint METOC Element Tables with assignments (Tables 3.8 and 3.9), continued.

```
WHERE ( [tbl1Joint Element].H1=[tblUAV (flat file)].H1 OR [tblUAV (flat file)].H1=4
OR
        ( [tbl1Joint Element].H1 IN (1,2,5) AND [tblUAV (flat file)].H1=3 )) AND

        ( [tbl1Joint Element].H2 = [tblUAV (flat file)].H2 OR [tblUAV (flat
file)].H2=1 OR [tbl1Joint Element].H2=1 OR
        ( [tbl1Joint Element].H2 IN (2,3) AND [tblUAV (flat file)].H2 IN (2,3) OR
        ( [tbl1Joint Element].H2 IN (4,5) AND [tblUAV (flat file)].H2 IN (4,5) )))
AND

         ( [tbl1Joint Element].V=[tblUAV (flat file)].V OR
         ( [tblUAV (flat file)].V = 2 AND [tbl1Joint Element].V IN (1,3,4) ) OR
         ( [tblUAV (flat file)].H2  IN (1,4,5) AND [tbl1Joint Element].V IN (7,8,9) )
OR
         ( [tblUAV (flat file)].H2  IN (1,3,5) AND [tbl1Joint Element].V = 8 )) AND

        ( [tbl1Joint Element].T1=[tblUAV (flat file)].T1 OR [tblUAV (flat file)].T1=1
OR
        ( [tbl1Joint Element].T1 IN (2,3) AND [tblUAV (flat file)].T1=3 )) AND

        ( [tbl1Joint Element].T2=[tblUAV (flat file)].T2 OR [tblUAV (flat file)].T2=1
OR
        ( [tbl1Joint Element].T2 IN (2,3) AND [tblUAV (flat file)].T2=3 )) AND

        ( [tbl1Joint Element].UAS=[tblUAV (flat file)].UAS OR [tblUAV (flat
file)].UAS=1 );
```

Table 3.11. Selected data from the Airborne Equipment Table.

Name	AC	D	A	E1	R1	A1	E2	R2	A2	E3	R3	A3	E4	R4	A4	E5	R5	A5
1	23	2	2	16	1	1	20	1	1	14	1	1	6	1	1	2	1	1
2	22	2	2	16	1	1	20	1	1	14	1	1	7	1	1	1	1	1
3	21	2	2	57	1	1	19	1	1	1	1	1	1	1	1	1	1	1
4	9	2	2	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	4	1	7	10	7	8	1	1	1	1	1	1	1	1	1	1	1	1
6	3	3	1	26	13	6	1	1	1	1	1	1	1	1	1	1	1	1
7	10	1	3	2	30	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	2	2	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	3	54	25	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	2	2	43	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	30	3	1	30	1	1	3	1	1	5	1	1	4	1	1	7	1	1
12	26	3	1	24	12	1	25	10	1	9	1	1	1	1	1	1	1	1
13	19	4	6	3	3	10	17	6	5	3	7	8	1	1	1	1	1	1
14	1	1	3	2	6	1	1	1	1	1	1	1	1	1	1	1	1	1
15	6	2	2	34	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	29	1	8	28	14	3	3	4	7	4	6	6	10	4	4	6	4	1
17	1	2	2	55	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	3	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	15	2	2	60	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	3	39	21	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	2	2	44	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	4	4	63	1	7	15	1	6	1	1	1	1	1	1	1	1	1
23	1	2	2	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	2	2	69	1	1	4	1	1	1	1	1	1	1	1	1	1	1
25	1	1	5	29	15	11	14	5	4	16	4	3	1	1	1	1	1	1

Table 3.11. Selected data from the Airborne Equipment Table, continued.

Name	AC	D	A	E1	R1	A1	E2	R2	A2	E3	R3	A3	E4	R4	A4	E5	R5	A5
26	1	1	3	53	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	3	1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	3	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
29	18	2	2	52	1	1	16	1	1	12	1	1	1	1	1	1	1	1
30	1	2	2	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31	32	3	1	30	1	1	3	1	1	5	1	1	1	1	1	1	1	1
32	1	2	2	73	1	1	6	1	1	1	1	1	1	1	1	1	1	1
33	2	3	1	37	19	5	1	1	1	1	1	1	1	1	1	1	1	1
34	1	1	3	36	1	1	27	1	1	5	1	1	2	1	1	1	1	1
35	33	3	1	30	1	1	3	1	1	5	1	1	1	1	1	1	1	1
36	1	1	3	33	1	1	1	1	1	1	1	1	1	1	1	1	1	1
37	1	2	2	68	1	1	12	1	1	11	1	1	1	1	1	1	1	1
38	1	1	3	25	1	1	1	1	1	1	1	1	1	1	1	1	1	1
39	1	1	3	67	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	13	2	2	48	1	1	1	1	1	1	1	1	1	1	1	1	1	1
41	12	2	2	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1
42	1	2	2	49	1	1	1	1	1	1	1	1	1	1	1	1	1	1
43	1	1	3	34	1	1	9	1	1	13	1	1	1	1	1	1	1	1
44	31	1	7	31	16	4	3	7	8	10	8	2	5	3	3	5	3	2
45	34	1	7	31	27	9	5	11	3	7	3	7	3	6	2	4	2	4
46	34	1	5	36	17	14	2	9	2	6	2	5	5	2	5	4	5	3
47	20	3	1	56	1	1	18	1	1	5	1	1	1	1	1	1	1	1
48	5	3	1	4	5	1	1	1	1	1	1	1	1	1	1	1	1	1
49	1	1	3	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	1	1	3	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1
51	14	2	2	50	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.11. Selected data from the Airborne Equipment Table, continued.

Name	AC	D	A	E1	R1	A1	E2	R2	A2	E3	R3	A3	E4	R4	A4	E5	R5	A5
52	8	2	2	66	1	1	1	1	1	1	1	1	1	1	1	1	1	1
53	7	3	1	40	22	1	1	1	1	1	1	1	1	1	1	1	1	1
54	1	2	2	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
55	1	2	2	45	1	1	1	1	1	1	1	1	1	1	1	1	1	1
56	1	2	2	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1
57	16	4	4	79	31	13	11	2	1	1	1	1	1	1	1	1	1	1
58	1	1	3	21	1	1	8	1	1	1	1	1	1	1	1	1	1	1
59	1	1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	1	2	2	64	1	1	23	1	1	15	1	1	1	1	1	1	1	1
61	1	1	3	2	4	1	1	1	1	1	1	1	1	1	1	1	1	1
62	11	2	2	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1
63	1	1	3	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1
64	1	1	3	2	18	1	1	1	1	1	1	1	1	1	1	1	1	1
65	24	2	2	61	1	1	21	1	1	1	1	1	1	1	1	1	1	1
66	1	2	2	27	1	1	1	1	1	1	1	1	1	1	1	1	1	1
67	1	2	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1
68	1	2	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1
69	1	2	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	1	2	2	58	1	1	1	1	1	1	1	1	1	1	1	1	1	1
71	1	2	2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1
72	1	1	3	2	8	1	1	1	1	1	1	1	1	1	1	1	1	1
73	1	1	3	7	23	1	1	1	1	1	1	1	1	1	1	1	1	1
74	1	1	3	19	10	1	1	1	1	1	1	1	1	1	1	1	1	1
75	1	1	3	18	9	1	1	1	1	1	1	1	1	1	1	1	1	1
76	1	1	3	18	26	1	1	1	1	1	1	1	1	1	1	1	1	1
77	1	1	3	38	20	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.11. Selected data from the Airborne Equipment Table, continued.

Name	AC	D	A	E1	R1	A1	E2	R2	A2	E3	R3	A3	E4	R4	A4	E5	R5	A5
78	1	2	2	78	1	1	1	1	1	1	1	1	1	1	1	1	1	1
79	28	1	5	29	24	1	7	8	1	19	5	1	1	1	1	1	1	1
80	1	1	3	47	1	1	1	1	1	1	1	1	1	1	1	1	1	1
81	1	2	2	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1
82	1	2	2	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1
83	1	2	2	76	1	1	1	1	1	1	1	1	1	1	1	1	1	1
84	1	2	2	15	1	1	28	1	1	1	1	1	1	1	1	1	1	1
85	1	2	2	15	1	1	28	1	1	1	1	1	1	1	1	1	1	1
86	1	2	2	71	1	1	1	1	1	1	1	1	1	1	1	1	1	1
87	25	3	1	65	28	12	24	1	1	17	1	1	8	1	1	3	1	1
88	1	1	3	75	1	1	1	1	1	1	1	1	1	1	1	1	1	1
89	1	2	2	42	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	1	1	3	41	1	1	1	1	1	1	1	1	1	1	1	1	1	1
91	1	2	2	51	1	1	1	1	1	1	1	1	1	1	1	1	1	1
92	1	1	3	36	1	1	27	1	1	5	1	1	2	1	1	1	1	1
93	27	1	7	23	11	2	26	3	1	18	9	4	9	5	1	1	1	1
94	1	1	3	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1
95	1	1	3	70	21	1	1	1	1	1	1	1	1	1	1	1	1	1
96	1	2	2	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
97	1	2	2	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1
98	1	2	2	42	1	1	1	1	1	1	1	1	1	1	1	1	1	1
99	1	1	3	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1
100	1	2	2	77	1	1	10	1	1	11	1	1	1	1	1	1	1	1
101	1	1	3	72	29	1	1	1	1	1	1	1	1	1	1	1	1	1
102	1	2	2	59	1	1	1	1	1	1	1	1	1	1	1	1	1	1
103	1	1	3	80	32	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.11. Selected data from the Airborne Equipment Table, continued.

Name	AC	D	A	E1	R1	A1	E2	R2	A2	E3	R3	A3	E4	R4	A4	E5	R5	A5
104	1	2	2	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
105	1	1	3	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1
106	17	2	2	74	1	1	13	1	1	8	1	1	1	1	1	1	1	1
107	1	1	3	62	1	1	22	1	1	2	1	1	1	1	1	1	1	1
108	1	2	2	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.12. Column heading legend.

Column Heading	**Acronym**
Equipment Name	Name
Acronym	AC
Department	D
Agency	A
Element1	E1
Range1	R1
Accuracy1	A1
Element2	E2
Range2	R2
Accuracy2	A2
Element3	E3
Range3	R3
Accuracy3	A3
Element4	E4
Range4	R4
Accuracy4	A4
Element5	E5
Range5	R5
Accuracy5	A5

Table 3.13. Name legend.

Name	**Airborne Equipment**
1	2 CHANNEL SELECTED ION CHEMICAL IONIZATION MASS SPECTROMETER)
2	4 CHANNEL SELECTED ION CHEMICAL IONIZATION MASS SPECTROMETER)
3	AIRBORNE DIODE LASER SPECTOMETER
4	AIRBORNE IMAGING MICROWAVE SPECTROMETER
5	AN/GMQ-33 TRANSPORTABLE CLOUD HEIGHT DETECTOR
6	ATMOSPHERIC EMITTED RADIANCE INTERFEROMETER
7	AUTOMATED CLASSIFIED AEROSOL DETECTOR
8	CARTRIDGE SAMPLER
9	CCN SPECTROMETER
10	CCN/IN COUNTER
11	CHEMICAL TACTICAL DROPSONDE
12	CLOUD DETECTION LIDAR
13	CLOUD DROPLET VIDEOSPECTROMETER
14	CLOUD, AEROSOL AND PRECIPITATION SPECTROMETER

Table 3.13. Name legend, continued.

Name	Airborne Equipment
15	COMMUNITY AIR INLET
16	COMPACT METEOR AND OCEAN DRIFTER (AN/WSQ-6) SERIES
17	CONDENSATION NUCLEI DETECTOR TS-3760
18	COUNTERFLOW VIRTUAL IMPACTOR (CIRPAS)
19	COUNTERFLOW VIRTUAL IMPACTOR (NCAR)
20	DEW POINT TEMPERATURE
21	DIFFERENTIAL MOBILITY ANALYZER WITH TSI-SMPS SOFTWARE
22	DUAL CHANNEL MICROWAVE RADIOMETER
23	EG&G MODEL 137 HYGROMETER
24	ELDORA
25	EYESAFE VISIOCEILOMETER
26	FILTER SAMPLING SYSTEM
27	FROST POINT HYGROMETER
28	FSSP - 100X
29	FTIR
30	GENERAL EASTERN MODEL 1011B
31	GPS TACTICAL DROPSONDE
32	HEIMANN KT19.85 IR RADIOMETER
33	HEMISPHERICAL OPTIMIZED NET RADIOMETER
34	HIGH ALTITUDE DROPSONDE
35	HIGH ALTITUDE METEOROLOGICAL DROPSONDE
36	HIGH RESOLUTION WATER VAPOR PROBE
37	HONEYWELL LASEREF INERTIAL REFERENCE SYSTEM
38	HOT WIRE LIQUID WATER CONTENT PROBE
39	HUMIDIGRAPH
40	ICE PARTICLE SAMPLER
41	INTERMITTENT SAMPLER
42	KING PROBE (HOTWIRE)
43	LIDAR, 360 DEG FOV
44	MANUAL OBSERVING SYSTEM
45	METEOROLOGICAL MEASURING SET (AN/TMQ-34) AF
46	METEOROLOGICAL MEASURING SET (AN/TMQ-34) ARMY
47	MICRO WEATHER STATION
48	MICROWAVE RADIOMETER
49	MOUDI CASCADE IMPACTOR
50	MULTI-WAVELENGTH INTEGRATING NEPHELOMETER
51	MULTIANGLE SPECTROMETER

Table 3.13. Name legend, continued.

Name	Airborne Equipment
52	MULTICHANNEL CLOUD RADIOMETER
53	MULTISPECTRAL PUSHBROOM IMAGING RADIOMETER
54	NCAR-MODIFIED EPPLEY PIR PYRGEOMETER
55	NCAR-MODIFIED EPPLEY PSP PYRANOMETER
56	NCAR-MODIFIED EPPLEY TUVR PYRANOMETER
57	NOAA OZONE AIRBORNE LIDAR
58	NON-DIRECTIONAL WAVE BUOY
59	NOVATEL DIFFERENTIAL GPS
60	NOx, NOy, O3 (CL)
61	OAP 260X
62	OPHIR III
63	PARTICLE MASS SPECTROMETER
64	PCASP - 100X
65	PEROXY RADICAL MASS SPECTROMETER
66	PMS - PCASP 100
67	PMS-FSSP-100
68	PMS-FSSP-260-X
69	PMS-FSSP-2D-C
70	PMS-FSSP-2D-D
71	PMS-FSSP-300
72	PP-2D PROBE
73	RADIOMETER, HYPER-SPECTRAL
74	RADIOMETER, INFRARED
75	RADIOMETER, PARTIAL SOLAR
76	RADIOMETER, TOTAL SOLAR
77	RADIOMETER, TUVR
78	RAF RADOME/IRS WIND GUST SYSTEM
79	REMOTE TACTICAL AREA PRESENT WEATHER SYSTEM
80	RING-DOWN CAVITY SPECTROMETER
81	ROSEMOUNT 102CV, 102DB
82	ROSEMOUNT 102E2AL
83	ROSEMOUNT ICING DETECTOR (MODEL 871FA212SC1)
84	ROSEMOUNT MODEL 1201F1 ABSOLUTE PRESSURE TRANSDUCER
85	ROSEMOUNT MODEL 1501 ABSOLUTE PRESSURE TRANSDUCER
86	SABL AEROSOL BACKSCATTER LIDAR
87	SOLAR SPECTRAL FLUX RADIOMETER
88	SOOT PHOTOMETER

Table 3.13. Name legend, continued.

Name	Airborne Equipment
89	SPANNING ACTINIC FLUX SPECTRORADIOMETERS
90	STABILIZED VIDEO IMAGING SYSTEM
91	SVR-SPECTRAL VEGETATION
92	TACTICAL DROPSONDE
93	TACTICAL PRESENT WEATHER SENSOR
94	TANS VECTOR
95	TEMPERATURE
96	TETHERED BALLOON
97	TETHERED BALLOON AIR SAMPLING PACKAGE
98	TOTAL ACTINIC FLUX
99	TRACE GAS MASS SPECTROMETER
100	TRIMBLE TRANS-III GPS RECEIVER
101	TURBULENCE, BAT SYSTEM
102	ULTRAFINE CN COUNTER
103	ULTRAFINE CONDENSATION PARTICLE COUNTER
104	UV
105	VARIABLE CUT IMPACTOR
106	WHOLE AIR SAMPLER
107	WIND, 5 HOLE PROBE
108	WINN ELECTRIC FIELD METERS

Table 3.14. Acronym legend.

AC	Acronym
1	(blank)
2	HONER
3	UAV AERI
4	TCHD
5	MWR
6	CAI
7	MPIR
8	MCR
9	AIMR
10	ACADS
11	OPHIR III
12	IS
13	VISP
14	MASP
15	CVI

Table 3.14. Acronym legend, continued.

AC	Acronym
16	NOAL
17	WAS (GCMS)
18	FTIR
19	CDVS
20	MWS
21	TDL
22	SI/CIMS-4
23	SI/CIMS-2
24	HO2 CIMS
25	SPFR
26	CDL
27	TAC PW
28	PWS
29	CMOD
30	CHEMSONDE
31	MOS
32	GPS-TDROP
33	HIMETSONDE
34	TMOS

Table 3.15. Federal Agency legend.

A	Federal Agency
1	(blank)
2	UCAR, NCAR/ATD
3	US NAVY (CIRPAS)
4	NOAA/ERL/ETL
5	US ARMY
6	NOAA/ATMOSPHERIC SCIENCES CENTER
7	US AIR FORCE
8	US NAVY

Table 3.16. Federal Agency's Department legend.

D	Agency Department
1	(blank)
2	UCAR, NCAR/ATD
3	US NAVY (CIRPAS)
4	NOAA/ERL/ETL
5	US ARMY

Table 3.16. Federal Agency's Department legend, continued.

D	Agency Department
6	NOAA/ATMOSPHERIC SCIENCES CENTER
7	US AIR FORCE
8	US NAVY

Table 3.17. Element1 legend.

E1	Element1
1	GPS WITH DIFFERENTIAL CORRECTION
2	PARTICLE SIZE DISTRIBUTION
3	DROPLETS
4	ATMOSPHERIC RADIATION (UPWARD VIEWING)
5	H2O
6	AMBIENT AIR TEMPERATURE
7	(blank)
8	COLLECTOR OF PARTICLES LARGER THAN SPECIFIED SIZE
9	FLUX
10	CLOUD BASES
11	HEMISPHERIC IR RADIATION
12	HEMISPHERIC UV RADIATION
13	MICROWAVE EMISSION
14	COLLECTOR OF SIZE CLASSIFIED PARTICLES
15	BAROMETRIC PRESSURE
16	HO
17	BACKSCATTER AND 7-170 DEG INTEGRAL SCATTER
18	PYRANOMETER
19	PYRGEOMETER
20	GPS POSITION, SPEED AND ALTITUDE
21	WAVE HEIGHT
22	AEROSOL PARTICLE SIZE AND COMPOSITION
23	VISUAL RANGE
24	AEROSOL PROFILING (100uJ/PULSE 5 kHz LASER)
25	LIQUID WATER VAPOR
26	UPWELLING OR DOWNWELLING ATMOSPHERIC RADIATION
27	AEROSOL SPECTRUM
28	BARO PRESSURE
29	VISIBILITY

Table 3.17. Element1 legend, continued.

E1	Element1
30	ATMOSPHERIC PRESSURE
31	WIND SPEED
32	TRACE GAS
33	WATER VAPOR CONCENTRATION
34	AEROSOLS
35	AMBIENT ELECTRICAL FIELD
36	TEMPERATURE
37	NET DIFFERENCE BETWEEN UPWELLING AND DOWNWELLING ATMOSPHERIC FLUXES
38	TOTAL ULTRAVIOLET RADIOMETER
39	CHILLED MIRROR DEVICE
40	COVERAGE OF UPWELLING ATMOSPHERIC RADIATION (NINE BANDS) TO STUDY CLOUD WATER/VAPOR
41	VISUAL IMAGERY
42	ACTINIC FLUX
43	CCN/IN COUNTER
44	CN PARTICLE DISTRIBUTION
45	HEMISPHERIC VISIBLE RADIATION
46	CLOUD DROPLET SPECTRUM
47	OH+OTHER SPECIES
48	CLOUD PARTICLE PROPERTIES
49	CLOUD LIQUID WATER
50	AEROSOL SIZE AND NUMBER
51	SPECTRAL VEGETATION INDEX
52	N2O, NO, NO2, HNO3
53	AEROSOL MASS AND COMPOSITION
54	CLOUD CONDENSATION NUCLEI
55	CN COUNTER
56	AIR TEMPERATURE
57	CO
58	HYDROMETEOROLOGICAL SPECTRUM
59	ULTRAFINE CN COUNTER
60	CLOUD DROPLET RESIDUALS AND CONDENSED WATER CONTENT
61	HO2
62	TAS
63	WATER VAPOR
64	NOx

Table 3.17. Element1 legend, continued.

E1	**Element1**
65	CLOUD WATER PHASE
66	CLOUD RADIATION
67	INTEGRAL SCATTER AT LOW AND HIGH HUMIDITY
68	3D POSITION
69	PRECIPITATION
70	TOTAL TEMPERATURE
71	AEROSOL BACKSCATTER
72	3-D WIND AND TEMPERATURE FLUCTUATIONS
73	SURFACE TEMPERATURE
74	CFCs, HCFCs, HFCS, CH4, C2-C5 ALKANES
75	DIFFERENTIAL FILTER TRANSMISSIVITY
76	ICE ACCUMULATION
77	TIME
78	AIR MOTION
79	OZONE
80	PARTICLE CONCENTRATION

Table 3.18. Range1 legend.

R1	**Range1**
1	(blank)
2	0.5 - 47.0μm
3	2-100μm
4	10 - 620μm
5	22GHz & 37GHz
6	0.3μm - 1.6mm
7	100 TO 3000 FT
8	200μm - 12.4mm
9	0.715 - 2.800μm
10	>4.0μm
11	10 M TO 75 KM
12	DIVERGENCE 53μrad WAVELENGTH 1.05μm
13	3-25μm (SPECTRAL)
14	850 TO 1054 MB
15	O TO 2 KM
16	0 TO 87.9 KTS
17	-50 TO 55 DEG C
18	0.1 - 3.0μm

Table 3.18. Range1 legend, continued.

R1	Range1
19	0.3-4μm (SHORTWAVE) 4-50μm (LONGWAVE)
20	0.295 - 0.385μm
21	-50 TO +50C
22	0.62-0.67, 0.86-0.90, 1.36-1.39, 1.58-1.64, 2.11-2.22, 3.55-3.93, 6.54-6.99, 8.40-8.70, 10.30-11.30 μm
23	0.3<lambda<13μm IN 610 CHANNELS
24	10 TO 150 KM
25	0.1%<Sc<2.0%
26	0.285 - 2.800μm
27	0 TO 55 KTS
28	300nm-2500nm SPECTRAL RANGE
29	f<40 Hz
30	0.003 TO 0.2μm
31	0.2 TO 3.5 KM
32	Dp>0.003μm

Table 3.19. Accuracy1 legend.

A1	Accuracy1
1	(blank)
2	2 TO 10 %
3	+- 1 MB
4	+- 3 %
5	3%, >170 degree FOV UPWARD AND DOWNWARD
6	0.5/cm (SPECTRAL) 1-10km (SPATIAL) UPWELLING OR DOWNWELLING
7	+- 0.8 mm
8	+- 100 FT
9	+- 2 kts
10	+- 0.5um
11	+- 30 %
12	5-10m RESOLUTION IN RADIANCE OR IRRADIANCE MODES
13	+- 10PPbv
14	+- 0.5 DEG C

Table 3.20. Element2 legend.

E2	**Element2**
1	(blank)
2	WIND SPEED
3	TEMPERATURE
4	WINDFIELDS
5	WIND DIRECTION
6	SKY TEMPERATURE
7	RAIN RATE
8	WAVE PERIOD
9	WINDS
10	3D POSITION
11	AERO. BACKSCAT
12	ALTITUDE
13	C1-C2 CHLOROCARBONS, HALONS, METHYL HALIDES
14	CLOUD HEIGHT
15	CLOUD LIQUID
16	CO, O3, F-11, F-12
17	FLOW RATE
18	GROUND TEMPERATURE
19	H2O
20	H2SO4
21	HO2+R02
22	MEAN WIND
23	NOy
24	OPTICAL DEPTH
25	OPTICALLY THIN CLOUD PROFILING (COAXIAL CCD CAMERA)
26	PRECIP TYPE
27	PRESSURE
28	PRESSURE ALTITUDE

Table 3.21. Range2 legend.

R2	**Range2**
1	(blank)
2	0.2 TO 3.5 KM
3	(COMMENTS)
4	-30 TO 46 DEG C
5	500M TO 9.6 KM

Table 3.21. Range2 legend, continued.

R2	Range2
6	0-20Cm 3 /SEC
7	-30 TO 50 DEG C
8	0 TO 10"/HR
9	0 TO 50 KTS
10	ROTATABLE IN FLIGHT FOR ZENITH OR NADIR VIEWING
11	0 TO 360 DEG

Table 3.22. Accuracy2 legend.

A2	Accuracy2
1	(blank)
2	+- 2 KTS
3	+- 5 DEG
4	+- 15%
5	+- 1 Cm 3 /SEC
6	+- 10 %
7	+-.2 DEG C
8	+- 1 DEG C

Table 3.23. Element3 legend.

E3	Element3
1	(blank)
2	SLIP AND ATTACK ANGLES
3	TEMPERATURE
4	SEA SFC TEMP
5	RELATIVE HUMIDITY
6	WIND DIRECTION
7	BARO PRESSURE
8	BR, CL-METHANES, ALKYL NITRATES
9	CLOUD TOP OR BASE OF OPTICALLY THICK CLOUDS
10	DEW POINT
11	GROUND SPEED
12	HCL, JF, HCN, COS, SO2, CH4, C2H6
13	HIGH RESOLUTION TURBULENCE
14	MSA
15	O3

Table 3.23. Element3 legend, continued.

E3	**Element3**
16	OBSCURANT
17	PARTICLE SIZE
18	PRECIP AMOUNT
19	PRESENT WX

Table 3.24. Range3 legend.

R3	**Range3**
1	(blank)
2	0 TO 360 DEG
3	640 TO 1060 MB
4	0 TO 2 KM
5	SNOW,RAIN,FOG
6	-5 TO 35 DEG C
7	-50 TO 45 DEG C
8	-50 TO 50 DEG C
9	0 TO 10"

Table 3.25. Accuracy3 legend.

A3	**Accuracy3**
1	(blank)
2	+- 2 DEG C
3	+- 5 %
4	+- 10 %
5	+- 5 DEG
6	+- .2 DEG C
7	+- .7 MB
8	+- 1 C DEG

Table 3.26. Element4 legend.

E4	**Element4**
1	(blank)
2	WIND
3	TEMPERATURE
4	WINDS
5	BARO PRESSURE
6	DMSO
7	HNO3

Table 3.26. Element4 legend, continued.

E4	**Element4**
8	LIQUID/ICE WATER PATH
9	PRECIP INTENSE
10	SUB SFC TEMP

Table 3.27. Range4 legend.

R4	**Range4**
1	(blank)
2	140 TO 1060 MB
3	600 TO 1100 MB
4	-9 TO 35 DEG C
5	LIGHT,MOD,HEAVY
6	-51 TO 55 DEG C

Table 3.28. Accuracy4 legend.

A4	**Accuracy4**
1	(blank)
2	+- .5 DEG C
3	+- .5 MB
4	+- .2 DEG C
5	+- .7 MB

Table 3.29. Element5 legend.

E5	**Element5**
1	(blank)
2	DMSO2
3	LIQUID/ICE WATER CONTENT
4	DEW POINT TEMP
5	RAIN AMOUNT
6	AMBIENT NOISE
7	CHEMICALS (DETECT, CLASSIFY, QUANTIFY)

Table 3.30. Range5 legend.

1	(blank)
2	-51 TO 55 DEG C
3	0 TO 4 "
4	5 HZ TO 5 KHZ
5	-40 TO 55 DEG C

Table 3.31. Accuracy5 legend.

A5	**Accuracy5**
1	(blank)
2	+- .05 "
3	+- 1 %
4	+-1 TO 8 DEG C

IV. RESULTS

After performing the query (Table 3.10) on the spatial and temporal scale-assigned RPA Table (Table 3.9) and Joint METOC Element Table (Table 3.8), the results may be used to rank RPA's according to their efficiency in collecting disparate, multiple METOC Elements (total possible of 185). Herein, "successful" is defined as the ability to collect several different, non-prioritized METOC Elements.

As currently assigned and queried, the Bell Eagle Eye (most successful RPA), could potentially (depending on instrumentation) position itself spatially and temporally in the unperturbed air stream to collect more METOC Elements than any other RPA listed. It's "**H1 H2 V T1 T2 UAS**" assignment reflects its "MICRO/MESOSCALE (<1 km - <400 km)" operating radius, "COMBINE"d operation over land or ocean, "SFC/UA" profiling ability, "HIGH AMOUNT OF TIME" spendable in one location (hover), "HIGH REFRESH RATE (<1 hr.)" indicating high endurance and METOC Elements measurable outside of propeller or rotor/perturbed air stream. See Table 4.1.

Table 4.1. Most successful RPA (refer to RPA Table for complete details).

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
3	1	2	1	1	1	USA	BELL EAGLE EYE	TILT-ROTOR

The best possible "**H1 H2 V T1 T2 UAS**" ranking would be "4 1 2 1 1 1," which would potentially measure 177 out of 185 METOC Elements, depending on instrumentation. See Table 4.2.

Table 4.2. Most successful RPA possible.

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
4	1	2	1	1	1	XXX	BEST POSSIBLE	FUTURISTIC

The Bell Eagle Eye (success rating "3 1 2 1 1 1") with a slightly larger control radius would reach "best possible" status. Thus modified, such an airframe could potentially measure every stated atmospheric METOC requirement and most oceanographic METOC requirements as well, with air-dropped oceanographic profiling insturments. Table 4.3 lists METOC Elements determined not generally measurable from RPA aircraft.

Table 4.3. "4 1 2 1 1 1" Unmeasured METOC Elements.
Archeological Sites/Wrecks
Bottom Composition
Bottom Currents
Bottom Gradient
Bottom Loss
Bottom Reverb. (active)
Bottom Roughness
Sub-Bottom Profiles

The CL-327 and -427 (Table 4.4) have a less capable "**H1 H2 V T1 T2 UAS**" assignment than the Bell Eagle Eye due to the location of the payload bay underneath the propellers. This position would continuously subject the payload to a perturbed air stream in the propeller wash. This situation could perhaps be avoided by the adoption of a construction employed by the Sikorsky Cypher which elevates the payload away from (and above) the propellers. The Insitu Aerosonde differs from Best possible in this study only due to its inability to hover. The Daedalus STF-9 resides in this category due to its limited endurance prohibiting a higher (**T2**) Refresh Rate assignment.

Table 4.4. Extremely successful RPA's (refer to RPA Table for complete details).

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
3	1	2	1	1	2	CANADA	CL-427	MULTIROLE VTOL
3	1	2	1	1	2	CANADA	CL-327 GUARDIAN	MULTIROLE VTOL
4	1	2	3	1	1	USA	INSITU AEROSONDE	LONG-RANGE/ ENDURANCE
3	1	2	1	3	1	USA	DAEDALUS STF-9	V/STOL

The predominant "**H1 H2 V T1 T2 UAS**" assignment in the extremely successful RPA category (Table 4.5) is "3 1 2 1 3 2." The limiting success factor in this category is the inability of the payload to escape propeller wash. A notable exception to this general limitation of the category is the Sikorsky Cypher. The Russian Kamov Ka-137 and USA Boeing Canard Rotor/Wing, in addition to their payloads' inability to escape rotor wash, suffer in the success ratings due to their slightly reduced endurance (a "3" entry in the "**T2**" column).

Table 4.5. Extremely successful RPA's (refer to RPA Table for complete details).

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
3	1	2	1	3	2	FRANCE	CAC SYSTEMES DRAGON FLY HELIOT	MULTI-MISSION OPTIONALLY PILOTED HELICOPTER
3	1	2	1	3	2	FRANCE	TECHNO SUD VIGILANT F2000	SMALL CLOSE RANGE OBSERVATION

Table 4.5. Extremely successful RPA's, continued.

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
3	1	2	1	3	2	GERMANY	DORNIER SEAMOS LV	MARITIME RECONN AND TARGET ACQUISITION
3	1	2	1	3	2	SWEDEN	TECHMENT MIDGET RPG	CLOSE RANGE OBSERVATION/ SURVEILLANCE
3	3	2	1	3	1	USA	SIKORSKY CYPHER	VTOL, CLOSE RANGE
4	1	2	1	3	2	RUSSIA	KAMOV KA-137	MULTI-PURPOSE HELICOPTER
4	1	2	1	3	2	USA	BOEING CANARD ROTOR/ WING	VTOL RECONN AND SURV

Table 4.6. Highly successful RPA's (refer to RPA Table for complete details).

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
3	3	2	1	3	2	AUSTRIA	SCHIEBEL CAMCOPTER	UNMANNED HELICOPTER
3	3	2	1	3	1	CANADA	BRISTOL AEROSPACE HOKUM-X	MANNED AND UNMANNED FULL-SCALE AERIAL TARGET
3	1	2	3	1	2	CANADA	CL-227 SENTINEL	RECOVERABLE VTOL MULTI-APPLICATION
3	3	2	3	3	1	USA	FREEWING TILT-BODY	EXPERIMENTAL MULTI-ROLE

All RPA entries in the Moderately successful category (Table 4.7) have "**H1 H2 V T1 T2 UAS**' assignments of "4 1 2 2 1 1" or "3 1 2 2 1 1." The only factor limiting this category's success is the relatively "LOW AMOUNT OF TIME (<1 sec.)" they can spend on any one measurement in space (no hover or extremely tight turning ability). This is the most successful non-hovering aircraft category for prosecution of diverse METOC Elements.

Table 4.7. Moderately successful RPA's (refer to RPA Table for complete details).

H1	**H2**	**V**	**T1**	**T2**	**UAS**	**COUNTRY**	**NAME**	**TYPE**
3	1	2	2	1	1	INTER-NATIONAL	TRW/IAI BQM-155A Hunter	SHORT RANGE RECONN, SURV AND TGT ACQ
3	1	2	2	1	1	INTER-NATIONAL	TRW/IAI BQM-155A E-Hunter	SHORT RANGE RECONN, SURV AND TGT ACQ
3	1	2	2	1	1	ISRAEL	SILVER ARROW HERMES 450	HIGH-ALTITUDE, LONG-ENDURANCE
4	1	2	2	1	1	ISRAEL	IAI HERON SHORT WING	HIGH ALTITUDE LONG RANGE/LONG ENDURANCE
4	1	2	2	1	1	ISRAEL	IAI HERON TURBO PROP	HIGH ALTITUDE LONG RANGE/LONG ENDURANCE
3	1	2	2	1	1	ISRAEL	IAI SEARCHER	LONG-ENDURANCE MULTI-ROLE
3	1	2	2	1	1	ITALY	METEOR MIRACH 26	CLOSE-RANGE TACTICAL
3	1	2	2	1	1	PORTUGAL	IST/OGMA ARMOR X7	CIVIL RESEARCH

Table 4.7. Moderately successful RPA's, continued.

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
4	1	2	2	1	1	RUSSIA	TUPOLEV TU-141 STRIZH	RECONN/SURV, JET POWERED LONG RANGE
3	1	2	2	1	1	USA	TCOM 32M AND 71M	HELIUM-FILLED, NON-RIGID AEROSTATS
4	1	2	2	1	1	USA	AEROMET AURA	SURROGATE UAV, OPTIONALLY MANNED
3	1	2	2	1	1	USA	AEROVIR-ONMENT PATH FINDER	SOLAR-POWERED EXPERIMENTAL
3	1	2	2	1	1	USA	AAI SHADOW 600	MULTI-ROLE
4	1	2	2	1	1	USA	AURORA FLIGHT SCIENCES THESEUS	HIGH-ALTITUDE LONG ENDURANCE ATMOSPHERIC RESEARCH
4	1	2	2	1	1	USA	GENERAL ATOMICS ALTUS	HIGH-ALTITUDE SCIENTIFIC RESEARCH
4	1	2	2	1	1	USA	GENERAL ATOMICS GNAT 750	ALL-ALTITUDE, MULTIMISSION, LONG ENDURANCE
4	1	2	2	1	1	USA	GENERAL ATOMICS RQ-1A PREDATOR	MEDIUM ALTITUDE, TACTICAL ENDURANCE
4	1	2	2	1	1	USA	GENERAL ATOMICS I-GNAT	ALL-ALTITUDE, MULTIMISSION, LONG ENDURANCE

Table 4.7. Moderately successful RPA's, continued.

H1	H2	V	T1	T2	UAS	COUNTRY	NAME	TYPE
4	1	2	2	1	1	USA	LOCKHEED MARTIN/ BOEING RQ-3A DARKSTAR (TIER III-)	LOW OBSERVABLE, HIGH ALTITUDE ENDURANCE TACTICAL
4	1	2	2	1	1	USA	TELEDYNE RYAN MODEL 410	MULTIROLE
4	1	2	2	1	1	USA	TELEDYNE RYAN RQ-4A GLOBAL HAWK (TIER II+)	HIGH ALTITUDE ENDURANCE SURV
4	1	2	2	1	1	USA	TELEDYNE RYAN SCARAB	RECONN, TACTICAL
4	1	2	2	1	1	USA	FRONTIER SYSTEMS ARROW	HIGH-ALTITUDE ENDURANCE
4	1	2	2	1	1	USA	FRONTIER SYSTEMS SHADOW	HIGH-ALTITUDE ENDURANCE
4	1	2	2	1	1	USA	FRONTIER SYSTEMS W570A	HIGH-ALTITUDE ENDURANCE
4	1	2	2	1	1	YUGOSLAVIA	SDPR VBL-2000	MULTIROLE

Tropical Storms, as presently assigned and queried, bears the most restrictive collective METOC assignment "**H1 H2 V T1 T2 UAS**" possible, "4 1 2 1 1 1."

Table 4.8. Most difficult METOC Element to prosecute.

Element	H1	H2	V	T1	T2	UAS
Tropical Storms	4	1	2	1	1	1

As has been demonstrated, no RPA in existence will measure this METOC Element. For scientific researchers and military operators alike, upon encountering similar problems using these databases the suggested steps to follow are the same: Break the METOC Element down into (presumably less restrictive) sub-Elements, then re-query. The following METOC sub-Elements and their less restrictive rankings, when entered into the tbl1Joint Element database table, will generate candidate RPA's for their measurement, as illustrated in Table 4.9.

Table 4.9. Tropical Storm sub-Elements.

Element	**H1**	**H2**	**V**	**T1**	**T2**	**UAS**
Tropical Storm Wind Speed/Direction	2	5	2	3	3	1
Tropical Storm Temperature	2	4	2	2	3	1
Tropical Storm Moisture	2	4	2	3	3	1
Tropical Storm Stratospheric Temperature	2	5	3	2	3	1
Tropical Storm Stratospheric Wind/Direction	2	1	3	3	3	1

Although some Tropical Storms sub-Elements have several RPA's listed capable enough to complete their measurement, three candidate RPA's appear in common for all five sub-Elements; the Bell Eagle Eye, the Daedalus STF-9 and the Insitu Aerosonde. The interested user would refer to the tblUAV (flat file) for specifics on RPA airframes of interest. The further the METOC Element is broken down the more candidate RPA's the query will produce.

If the interested user instead brings forth a range of METOC Elements of interest, the query results obtained could again be used either for optimal RPA choice, combinations or lowest operating cost. One method to accomplish this would be to run the query, enter the "Advanced Filter/Sort" function of Microsoft Access and insert the "Element" column of "qryMATCHES" into the "Field" position of the filter. The entry format for the "Criteria" field would look, for example, like the following (providing these entries already existed in the tbl1Joint Element table): ' "Tropical Storm Wind Speed/Direction" Or "Tropical Storm Temperature" Or "Tropical Storm Stratospheric

Wind/Direction" Or "Tropical Storm Stratospheric Temperature" Or "Tropical Storm Moisture".'

V. CONCLUSIONS

This thesis, along with its accompanying databases (available at www.met.nps.navy.mil/thesis/rstanton), takes what at first may resemble an interesting thought-experiment and demonstrates its practicality for meteorological/oceanographic instrument designers, remotely piloted aircraft designers and mission planners/operators. METOC instrument designers can identify at a glance what airborne instruments exist or are in planning stages and judge their ranges of measurement and accuracies. The first complete Joint METOC Requirements Database (Army, Air Force, Navy, Marine) exists in a separate database. RPA designers can query proposed changes to aircraft design and know how a modification would affect METOC Element-gathering success before the physical modification took place.

Original systematic biases may be modified, eliminated or enhanced according to individual preferences simply by overwriting spatial, temporal and air stream assignments and re-querying the data. The databases are easily expandable: Autonomous Underwater Vehicles (and further classes of autonomous vehicles) could easily be included in a re-titled "Robotics" Table, METOC Elements will continue to be refined (easily incorporated), production of more capable (and smaller) airborne instruments will require continual updating of that database.

The RPA's that fared most successfully in their ability to prosecute diverse Joint METOC Elements have several general characteristics in common:

- They possess at least over-the-horizon controllability/programmability and generally extend to great operating ranges
- Launches and recoveries are very flexible, not precluding ship operations,
- Flight characteristics include an ability to conduct atmospheric profiles,
- The RPA's can dwell near a point in space longer than their competitors,

- The RPA's can revisit a datum several times based on their excellent endurance,
- Meteorological/Oceanographic data collected by such instrument-carrying RPA's is not subject to deleterious effects of propeller or rotor wash due to RPA design.

The Category I Bell Eagle Eye's "**H1**(Horizontal1) **H2**(Horizontal2) **V**(Vertical) **T1**(Time1) **T2**(Time2) **UAS**(Unperturbed Air Stream)" assignment (Table 4.1) reflects its "MICRO/MESOSCALE (<1 km - <400 km)" operating radius, "COMBINE"d operation over land or ocean, "SFC/UA" profiling ability, "HIGH AMOUNT OF TIME" available to dwell in one location (hover), "HIGH REFRESH RATE (<1 hr.)" indicating high endurance and METOC Elements measurable outside of propeller or rotor/perturbed air stream. As presently assigned and queried, it is the most "successful" remotely piloted aircraft in existence (defined as the ability to collect the most amount of disparate, unranked METOC Elements of Measurement (e.g. Absolute Humidity, Temperature, Dew Point, Beach Characteristics, etc)). Category V, Moderately Successful RPA's is the first large category to deal with non-hovering aircraft.

Conversely, Tropical Storms (Table 4.8) is the most restrictive METOC Element listed (or possible). No single RPA exists to fully measure them..The thesis demonstrates two separate methods of describing Tropical Storm measurement with RPA's (or any other difficult METOC Element), one dealing with breaking the METOC Element into sub-Elements (database additions) and the other demonstrating how to query a set of outside Elements (query design).

The next logical step for this research would be to include all classes of autonomous vehicles able to collect METOC Elements of Measurement. Secondly, the METOC Elements should be prioritized in concert with the Services. Thirdly, instrumentation compatibility with individual RPA's should be addressed. Completing these steps will enable ever more subtle and powerful queries.

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